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FARMER'S LUNG—A FORM OF PNEUMOCONIOSIS DUE TO ORGANIC DUSTS*

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A DISEASE entity of considerable importance to agricultural workers, and particularly to those engaged in dairy farming, has received but scant attention in the American literature. In Great Britain and Scandinavia the illness has been described variously as "farmer's lung,"[40,85] "thresher's lung,"[86] "harvester's lung,"[26] "bronchomycosis feniseciorum,"[29,30] a form of lung mycosis,[4] and as a pneumoconiosis.[23] Finally, "hemp disease,"[5] as reported in Norway, would appear to be similar to these other entities.

In 1932, Campbell[11] reported 5 cases of illness developing after exposure to the dust of unusually moldy hay, the result of a very rainy season the previous summer. Onset was similar with noticeable shortness of breath for some weeks climaxed by severe dyspnea and cyanosis. There was a rather unproductive cough, mild pyrexia, weight loss, and a feeling of "tightness" in the chest. No causative factor was found, and there appeared to be no correlation with the fungi cultured.

Fawcitt[29,30,31] regarded the disease as a true mycosis, applying the term "bronchomycosis feniseciorum" (of haymakers or harvesters). He stated that the infection could be mixed, involving Aspergillus, Penicillium, and Mucor, and pointed out the efficacy of iodides in treating the disease. The criterion for diagnosis, in his opinion, was established by producing lesions in the lungs of guinea pigs on inoculation of fungi cultured from clinical cases. Exacerbation of symptoms on repeated exposures to moldy dust was discussed, bringing up the possibility of sensitization of the lungs to fungi.

In another discussion of the disease, Duncan[22] questioned the role of fungi in its production and stressed the progressive character of the lung changes with successive seasonal recurrence. He, too, discussed the factor of sensitization, pointing out, however, that unlike asthmatics the cases in question are dyspneic because of inability to inspire adequately rather than to effect adequate expiration.

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Törnell[86] regards the problem as a fungoid disease incurred from moldy grain with the organic dust inhalations serving as a substrate for infection by bacteria or fungi. Chronic involvement and early response to iodides are discussed. Interestingly, he points out the similarity to sarcoidosis in regard to both tuberculin anergy and roentgenologic appearances. Prophylaxis is discussed, and the wearing of a mask when handling "burned" grain is recommended.

Pneumoconiosis among British dock workers handling grain and seeds has been described by Dunner, Hermon and Bagnall.[23] Men exposed to clouds of grain dust for many years developed a productive cough and dyspnea. Although the authors state that there is no similarity between their cases and Fawcitt's cases among agricultural workers, their cases do resemble the late stages of a disease involved largely with inhalation of organic dusts.

In 1950, editorial comment in England[26] labelled the disease "harvester's lung," stating it was due to infection either by Aspergillus or Penicillium and recommending iodides in treatment.

Fuller[40] reviewed the subject in 1953, pointing out the identical clinical and roentgenologic findings in his cases and those of others. He divided the disease into three phases: (1) The acute isolated attack of relatively mild nature lasting but a few days; (2) a subacute and more chronic condition which shows a spontaneous tendency to recover; and (3) the chronic and irreversible phase.

Thirty-two cases were collected by Fuller, most falling into his phase two classification. The dairyman shaking down moldy hay for the cattle in the winter months and the member of a threshing team handling moldy grain were the two types of worker most susceptible. Mold cultures demonstrated the spore content of cowshed air to be 10 times that of outside air, while the atmospheric spore content after bringing in hay was 70 times that of the outside air. No characteristic organisms were cultured, the sputa yielding a wide variety of organisms, including 15 per cent positive cultures for Candida albicans among 95 controls.

Extracts of both good and moldy hay produced positive intradermal reactions in 10 patients and 1 control, while pure mold cultures gave little and only haphazard response. In discussing the etiology of the disease, Fuller raises the question of sensitization, though pointing out the dissimilarities to asthma, and mentions the experimental work of Zettergren[93] involving production of granulomata in rabbits' lungs.

Fuller concludes that his cases represent an occupational disease which is more common than usually realized and which is "the cause of a great deal of minor illness amongst farm-workers." In the cases to be presented, however, the disease assumes the proportions of a major entity, involving factors of permanent disability which have become apparent only on follow-up study.

In 1953, Studdert[85] also reviewed the subject and presented 12 cases of the disease, 6 probable and 6 confirmed. He notes that an eighteen year follow-up of one of Campbell's cases revealed only fibrosis and emphysema.

Studdert states that many farmers remember cases of sudden death following acute chest symptoms in men working all day in some of the old ill-ventilated barns, and certainly this could represent a not unsuspected complication of anaphylactic type if true sensitization to moldy dust occurs. He also states that "broken windedness" in horses is attributed to the feeding of moldy hay. Although the illness is reported to be rare in hospital practice, he found, on circularizing country practitioners, that it was relatively common. In the cases presented was the first report of a woman, who developed the disease after sweeping out a barn in preparation for corn storage.

Studdert discusses the clinical findings thoroughly, pointing out that the syndrome may occur after exposure to moldy

vegetable dust of any kind during stacking, threshing, baling, forking of hay, or in sweeping out a barn. Distinction from a true asthmatic attack due to such dust must be made, and he notes that whereas dust frequently gives rise to complaints of eye and nose irritation, these are not features complained of in these cases. Onset of symptoms occurred in twelve hours, and if delayed more than twenty-four hours, he felt an alternative diagnosis must be considered. The cases to be presented, however, demonstrate other variations in the clinical onset of the disease.

Pleurisy was not considered a complication by Studdert, and if present, he felt it made the diagnosis suspect. None of the cases presented by him complained of hemoptysis. The roentgenographic picture cleared in six to eight weeks, and after three months, his patients appeared to be well, although there was a tendency for the condition to recur on re-exposure. Contrary to the experience gained in many of the cases to be presented, Studdert states, "No diminution in vital capacity has been noted in the follow-up of the present series over one to five years." Sputum cultures yielded Aspergilli, Penicillium, B. subtilis, and Candida albicans in many of both the proved and probable cases. The incriminated dusts yielded a comparable growth of mixed organisms, and Studdert felt this simply represented evidence that the patient had inhaled the dust recently, but in no way that it proved the presence of active infectious disease in the bronchi or lungs. Skin tests with extracts of the dust and stock solutions of the Aspergillus, Penicillium, and Mucor revealed no specific pattern. No effective therapeutic agent was discovered, and he even discounts the use of iodides. Antihistaminic drugs produced little effect, and the antibiotics were of limited value in preventing secondary infection.

The possibility of a fungus as the etiologic agent in the disease is discounted by Studdert, who considered the process a pulmonary reaction to an inhaled irritant.

In the only article found in the American literature confined to this subject, Soucheray[84] reports 3 cases of the disease in farmers exposed to dust from moldy corn silage and subtitles his article "A Form of Bronchopulmonary Moniliasis." Although the works of Ikeda[55] and Zettergren[93] are quoted in support of the fungus etiology of the disease, the author does not present his cases as authenticated pulmonary moniliasis in view of the difficulty in establishing such a diagnosis without lung biopsy and tissue culture.

THE CURRENT SERIES

Twenty-seven cases have been collected with some followed up to a period of six years. Recent follow-up examination has been carried out to evaluate the presence of complications and permanent disability. As in most disease processes, gradations in severity occurred, but questionable variations of the syndrome have been excluded, as have all cases representing the more commonly known manifestations of allergy.

CLINICAL MANIFESTATIONS

The syndrome develops after exposure to dusts which are usually moldy and most often associated with the handling of moldy hay or silage. Moldy grains were occasionally indicted, and even plain silage was not infrequently at fault. Symptoms in a few followed inhalation of the "steam" of silage, but this occurred weeks after ensiling, on "opening" the silo and therefore would not likely be due to nitrous dioxide, the agent believed responsible for silo-filler's disease as recently described by Delaney, Schmidt and Stroebel[19] and Lowry and Schuman.[65] It is of interest that 1 of the cases of the first group had had respiratory symptoms following work with old silage before his acute terminal illness on exposure to fresh ensilage.

Shredded corn stalks and dust from fresh hay and grain were also responsible for some cases despite repeated denial of any element of associated mold. Following

TABLE I

FREQUENCY OF MAJOR COMPLAINTS IN ACUTE FARMER'S LUNG

Complaint	Number of Patients	Percentage of Series
Dyspnea	27	100
Cough	22	81
(nonproductive)	(16)	(59)
(productive)	(6)	(22)
Fever and chills	19	70
Night sweats	18	67
Weight loss	17	63

the first attack, most cases reported recurrent symptoms after exposure, not only to the original offending agent, but to a wide variety of the dusts mentioned, strongly suggesting a very broad cross sensitization.

A minor form of the disease apparently occurs involving dyspnea, chills and fever and night sweats lasting a day or two after exposure to clouds of dust associated with threshing fresh grain. The symptoms pass quickly, and the few cases seen complained of no permanent disability. None are included in this series.

Despite variation in severity, a typical acute episode following exposure to the causative agent is characterized by increasing dyspnea, cough which is usually nonproductive, fever and chills, night sweats and weight loss. The frequency of these complaints is listed in Table I.

Dyspnea occurred in every case. Although mild to moderate in a few, in most it was the major difficulty, not infrequently associated with cyanosis and in several requiring administration of oxygen. The weight loss was severe when it occurred, varying from 5 to 65 pounds and averaging 29 pounds. A few patients complained of fatigue, muscle aching, headache or chest pain, and 3 stressed the terrible odor of the drenching sweats they experienced. Seventeen patients were hospitalized at some time during the course of illness.

Despite recovery after a variable period of weeks, the patient complained frequently of permanent limitation of exertional capacity. Following the initial attack, later exposure to the inciting agent, or to one of a variety of such agents, precipitated recurrence of symptoms, particularly dyspnea. In some, exposure to even the spore laden barn air may be responsible for such recurrence.

After repeated episodes, progressive disability occurred with pulmonary emphysema, fibrosis and right-sided heart strain. These patients almost invariably complained of recurrent seasonal "colds" or "fullness" in the chest on exposure to dusts which usually were caused by handling moldy hay or silage. In all cases the symptoms were far worse in the winter than in the summer.

The onset of the disease followed three clinical patterns, and the patients were almost evenly divided between these groups:

Group I (11 cases). These constituted the most spectacular cases with the acute attack following a single exposure to unusual quantities of the inciting agent, which was severely moldy hay, grain or silage in all but 1 case. The exception was exposed to silage "steam" on opening the silo.

Group II (9 cases). Symptoms occurred following repeated exposure to unusually moldy hay, grain or silage over a period of time, usually a winter season, with constant handling of the material. In only 1 case was exposure to moldy dust denied, by a farmer repeatedly exposed to fine particulate matter produced by grinding hay in a hammermill for feed. All other cases stressed the unusual moldy quality of the material for that particular year.

Group III (7 cases). These patients complained of symptoms of a variable degree of severity following exposure to different inciting agents over a period of years. The severe acute exacerbation then occurred without any one particularly outstanding episode of exposure. Interestingly, these patients were concerned mostly with apparent sensitization to corn silage rather than to moldy hay.

LABORATORY FINDINGS

No distinctive laboratory findings were apparent. Occasionally polycythemia was

noted during the acute attack with the hemoglobin level rising as high as 113 per cent (18 gm.). The white blood cell count was above normal in only a few cases. Temperatures were elevated frequently but not consistently so. When present, a temperature as high as 106° F. was observed with gradual subsidence in a few weeks' period.

Sputum cultures occasionally yielded Candida albicans, but not consistently, and were more often negative in the cases so examined. Endomyces was reported in 1 patient (Case XVI) by the Wisconsin State Laboratory of Hygiene. Smears and cultures for the tubercle bacillus were consistently negative.

When performed, in a few cases, agglutination tests for typhoid, paratyphoid, Proteus OX19 and Brucella abortus were negative. Vital capacity determinations done during the acute illness were decreased quite markedly.

FOLLOW-UP EXAMINATIONS

All but 1 of the patients in this series were re-examined during the early months of 1956. The history was re-evaluated in each case with particular regard to permanent sequelae, and various laboratory tests were done, including blood cell counts, vital capacity determinations, electrocardiograms, and a variety of skin tests for fungi. A progress roentgenogram of the chest was obtained in each case.

Of the 27 cases, 1 (Case III) died and was autopsied. Another (Case IX) has never entered the barn following his initial attack and does no farm work at present. It is apparent, however, that the disease is of major economic importance, for of the remaining 25 cases, 7 have given up farming entirely because of the illness, and another 7 continue to farm but have recurrent symptoms with a varying degree of disability.

Only 1 of the remaining 11 cases states that he is able to farm without exacerbation of symptoms on exposure to dusts. He, however, claims that his exertional capacity is impaired, despite a vital capacity which measures above normal levels. The other 10 continue to farm but are able to do so only by making necessary adjustments involving such devices as barn fans, respirators, or additional hired helpers. Most of the patients have learned to be exceedingly careful in avoiding offending dusts, and one is able to carry on only by reducing his dairy herd considerably.

Not a single case was encountered where the patient felt he had recovered completely and could return to unrestricted farming activities.

Ten patients demonstrated significant reduction in the vital capacity, with measurements ranging from 38 to 76 per cent of normal. All complained of quite marked dyspnea on mild exertion. Eight of them continue to farm, but it is anticipated that progressive disability will occur, forcing them to discontinue their occupation. Case V is considered to be quite critically ill, and Cases XIV and XIX in all probability will attain the same grave prognosis if they persist in their activities for they are severely incapacitated at present.

Nine patients demonstrated vital capacities in the low normal range (from 80–86 per cent). Seven of them complained of mild exertional dyspnea, and 2 stated they experienced mild dyspnea only on exposure to the barn atmosphere.

The remaining patients had vital capacities in the high normal range; yet 4 of these complained of limited capacity for work in contrast to previous capabilities.

The electrocardiogram of Case V is grossly abnormal with evidence of advanced chronic cor pulmonale. Fourteen additional abnormal electrocardiograms were obtained, and these revealed a variety of patterns. Five suggested right heart strain, 5 were abnormal without a specific pattern (2 of these showing left axis deviation), and 4 were suggestive of coronary insufficiency.

Follow-up blood cell counts demonstrated an hemoglobin level of over 100 per cent in 6 patients. Three were considered of clinical significance, ranging from 108 per cent to 120 per cent (16.8 gm. to

18.6 gm.) and felt to represent true compensatory polycythemia. These 3 patients, incidentally, are still on the farm.

Intradermal skin testing was done employing tuberculin, histoplasmin, polyvalent aspergillin, blastomycin, coccidioidin and antigen prepared from cultures of Candida albicans.* Marked anergy was encountered although the last named preparation yielded ten positive tests and five trace reactions. These, however, were not unexpected, for Conant[17] points out that 35 per cent of normal adults will demonstrate a positive reaction to this antigen. Only two positive reactors to tuberculin were found, and of the remaining intradermal tests, only one questionable reaction to aspergillin was seen and only one trace reaction to blastomycin. No positive reaction to histoplasmin was observed in the present series.

ROENTGENOLOGIC FINDINGS

The characteristic roentgenologic changes in the acute stage consist of a fine to coarse granular and nodular mottling scattered quite diffusely throughout both lung fields, although less prominent in the apices and peripheral bases, due, as pointed out by Felson,[34] to the smaller volume of parenchyma traversed by the roentgen ray in these areas. He stressed the nonspecific character of the lung changes found in a large number of acute diseases giving rise to a "miliary" appearance. Felson and Heublein,[36] in a thorough discussion of the subject, also emphasize the difficulties in arriving at a diagnosis from the roentgenologic appearances alone in any given case of diffuse pulmonary lesions.

Changes on the chest roentgenogram may be minimal with the onset of symptoms, and, in some cases, followed exposure and such onset by long periods of time. In general, the appearance of roentgenographic changes coincided with the greatest severity of symptoms. Case XIII had developed cough and dyspnea after a single massive exposure to large quantities of dust from moldy shredded corn almost five months prior to his first examination. Symptoms increased in severity, particularly just before hospital admission. A chest roentgenogram on May 6, 1951, was essentially unremarkable (Fig. 1), but well marked limitation of diaphragmatic excursions was noted at fluoroscopy. In view of this and the patient's history and dyspnea, progress study was requested. Twelve days later, the fine granular appearing infiltrates anticipated in farmer's lung were demonstrated (Fig. 2). This case is not presented in detail, but sensitivity to barn atmosphere was incurred, and although the chest was essentially normal on examination in March, 1956, he complains of abnormal dyspnea on mild exertion.

Quite similarly, a routine photofluorographic examination of Case II was negative on admission to the hospital, although symptoms were marked, and it was only on follow-up examination that the changes usually found in this disease were revealed (Fig. 8).

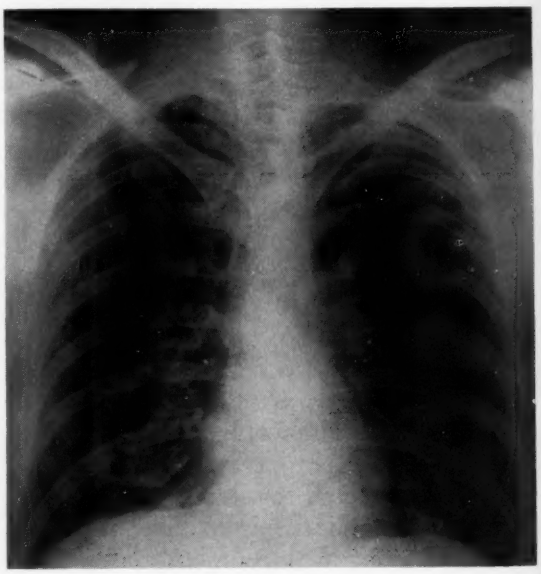

FIG. 1. Case XIII. Essentially unremarkable chest roentgenogram, May 6, 1951, despite symptoms increasing in severity since massive exposure to dust of moldy shredded corn the previous December. Dyspnea severe; diaphragmatic motion limited on fluoroscopic examination.

* Most of the antigenic materials so employed were obtained through the kindness of N. F. Conant, Ph.D., of Duke University.

Fig. 2. Case xiii. Roentgenogram of May 18, 1951, twelve days after Figure 1, demonstrating appearance of diffuse finely granular infiltrates seen in farmer's lung. Symptoms preceded roentgenographic changes to a marked degree. Patient responded to rest and iodides, but despite normal findings in 1956 complains of persisting limitation of exertional capacity.

Bothen[4] compares the individual lesions seen on the roentgenogram to snow flakes, down or cotton wool and points out the similarity to sarcoidosis. Törnell[87] also discusses the similarity to sarcoid involvement of the lung, and Paul[70] has commented that differentiation of the two entities may be impossible on roentgen evidence alone. In none of the cases presented, however, was significant hilar or mediastinal lymphadenopathy found. The presence of such lymph node enlargement, therefore, would weigh heavily against the diagnosis of farmer's lung.

Although the individual parenchymal lesions varied considerably in size and frequently appeared to be quite irregular and poorly circumscribed, a characteristic frequently noted was a very fine "sand storm" appearance consisting of uniformly distributed fine granular densities involving various areas of the lung. These individual lesions approximate a millimeter or less in diameter as seen on the roentgenograms and are discrete. Unfortunately, their size precludes satisfactory reproduction. Soucheray[84] feels that they most likely represent granulomata of the type produced in experimental animals by Ikeda[55] and Zettergren.[93] The granulomatous lesions found on lung biopsy in Case xxvi (Fig. 3) would lend support to this interpretation and discount the belief of Fawcitt[29] that the granular appearance is due to alveolar collapse because of bronchiolar obstruction. If progression occurs, coalescence may take place

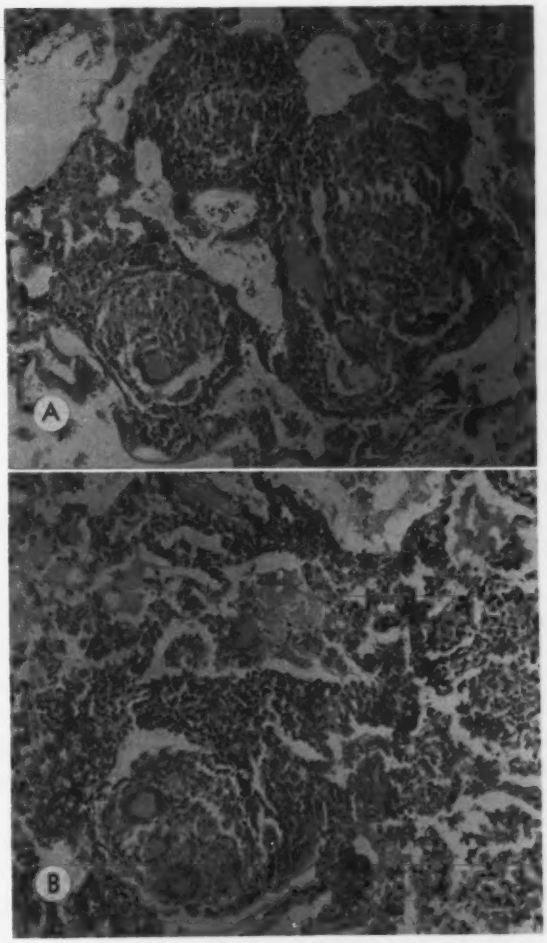

Fig. 3. Case xxvi. (*A*) Microphotograph (×150) showing noncaseating granulomatous process and some interstitial fibrosis. (*B*) Microphotograph (×150) from same lung biopsy demonstrating a single granuloma and a somewhat greater degree of interstitial fibrosis. Note the Langhans' type giant cells in both sections.

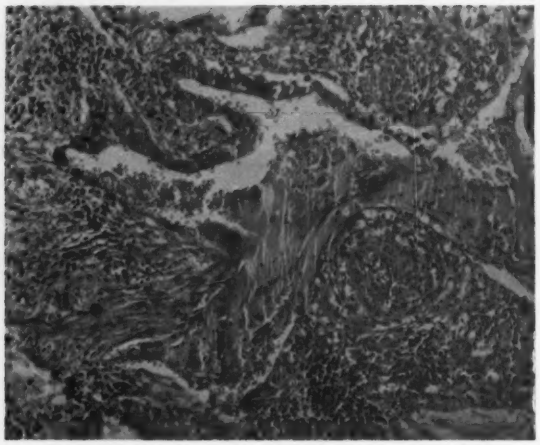

FIG. 4. Case III. Microphotograph (×150) demonstrating extensive interstitial fibrosis. Note single loosely knit epithelioid cell granuloma just below and to the right of center.

with larger conglomerate lesions and interstitial reaction obscuring much of the lung parenchyma (Case IX, Fig. 6).

Clearing is gradual, and although return to an apparently normal chest occurs after the acute attack, mild emphysema and scattered fibrotic strands are not infrequent. In the subacute stage of the disease, where continued exposure to the causative agent occurs, coarsening of the truncal markings may be observed compatible with an active interstitial process leading to fibrosis, pulmonary hypertension and eventually cor pulmonale (Case V, Fig. 16).

The final stage consists of severe pulmonary fibrosis and emphysema with accompanying right heart strain (Case XXIII, Fig. 17).

PATHOLOGY

Lung tissue for microscopic examination and culture has been limited necessarily in a benign disease process of this kind. In recent years, however, lung biopsy has become increasingly common, and in experienced hands entails no significant risk. With increasing use of this diagnostic aid, additional information should accumulate rapidly.

Dr. H. J. Conlon of Eau Claire, Wisconsin, has kindly reviewed the lung tissue sections available in 2 cases of the present series, and has submitted the following report regarding them:

Case XXVI. "Sections from the lung biopsy show numerous focal granulomata. These are noncaseating with infiltration of lymphocytes, histiocytes and adjacent fibrosis. There are striking numbers of giant cells of the Langhans' type scattered about in these lesions. In addition, there is diffuse interstitial fibrosis. In some of the granulomas there is formation of dense acellular collagen which appears to arise in the alveolar wall and bulge into the alveolar space. In a few areas the granulomata are beginning to coalesce and form a diffuse type of fibrosis involving both the alveolar wall and the alveolar space" (Fig. 3).

Case III (autopsy material). "Sections . . . show a far more advanced process. Here, there is a diffuse fibrosis with large amounts of acellular collagen which is dense in focal areas. There is, in addition, marked interstitial fibrosis with thick alveolar walls which are avascular. Giant cells are occasionally noted and a few focal granulomata are seen with epithelioid cells and lymphocytes. There is a superimposed acute inflammation which is considered terminal in nature. A stain for fungi, utilizing the periodic acid-Schiff technique demonstrates no organisms in either case" (Fig. 4).

In Conlon's opinion, the lesions of Case XXVI represent an early stage of the disease, and though the granulomata have a superficial similarity to sarcoidosis, he does not feel that on close evaluation they fit the criteria for that disease entity as outlined by Longcope and Freiman.[63] (See comment following report of Case XXVI.)

The second case was regarded as a far advanced lesion representing a scarred lung which had been the seat of repeated and chronic inflammation.

Sections of lung biopsies of additional cases were received independently for review and comparison from Lawton[61] and Jaeschke,[56] neither of whom has observed the number of granulomata seen in Case XXVI in their cases, though observing a

variable degree of interstitial fibrosis and granulomatous reaction. On review of all available tissues, Conlon concluded that their cases show an intermediate pattern between the early focal granulomata of Case xxvi and the diffuse nonspecific scarring representing the end point of the disease.

DIFFERENTIAL DIAGNOSIS

Pulmonary Moniliasis (C. albicans infection). In 1905, Castellani[13] had observed "tea-taster's cough" in Ceylon, ascribing the illness to a form of moniliasis. Since that time, numerous articles concerned with bronchopulmonary fungus infections, particularly Candida albicans, have appeared. Among others, Brown,[7] Carter,[12] the Flinns,[37] Oblath and associates,[69] and Reeves[74] have described a wide variety of clinical and roentgenographic findings. In most of the cases presented, the diagnosis was based on sputum cultures with occasional demonstration of pulmonary lesions in experimental animals subjected to inoculation with the strains isolated on such cultures. Response to iodides was felt to be supportive evidence of the diagnosis in similar groups of cases reported by Craven,[18] Johnston and Heydemann,[58] and Morin, Leblond and Filset.[67]

Hamman[48] felt that fungi frequently enter the lung as secondary invaders, complicating the pre-existing disease. Bakst, Hazard and Foley[1] point out that monilia are frequently secondary invaders in debilitating diseases, particularly in tuberculosis and lung carcinoma, and Norris[68] emphasizes the frequency of positive yeast cultures on sputum studies of patients with tuberculosis. The presence of monilia as a secondary invader in cases of bronchiectasis has been discussed by Peterson[72] who feels that the improvement of such patients on iodide therapy may be due to clearing of the secondary infection. According to Wylie and DeBlase[92] monilia fungi exist as saprophytes but under certain conditions, as in bronchitis, pneumonia or influenza, they may become virulent.

Ikeda[55] produced lesions in experimental animals, but these consisted of mycotic tumors which on occasion coalesced and progressed to abscess formation. In an earlier work, Ikeda[54] had presented a series of cases associated with positive sputum cultures for monilia and demonstration of yeast-like bodies in tissue sections. He stressed the frequency of the latter finding in cases of chronic pulmonary disease due to other causes and in discussing a case of chronic interstitial pneumonia of obscure etiology associated with bronchiectasis and abscesses, he concluded, "It cannot be definitely stated that the organism is the sole cause of this condition."

Autopsied cases reported as moniliasis are included in discussions by Cohen,[16] Jaffin,[57] and Oblath and co-workers.[69] No organisms, however, were discovered in the tissues, although the last group felt this was evidence of response to treatment. Bothen[4] reports an autopsied case of pulmonary fibrosis in a thresher and claims detection of mycelia in the interstitial tissues. Törnell[86] and Soucheray[84] also felt that thresher's lung and farmer's lung most likely represented a form of pulmonary moniliasis.

The failure to culture Candida albicans consistently in this illness, as well as the erratic response to intradermal testing with the antigen and failure to demonstrate the organism in the tissue specimens available, would discount the possibility of the fungus being the infectious cause of this disease. In addition, Dickie[21] has been unable to culture Candida albicans (or other organisms) from lung biopsy material in several cases. Finally, it has been impossible to isolate C. albicans from the myriad fungi cultured from several samples of moldy hay and silage. Certainly the widely varying clinical and roentgenographic findings attributed to pulmonary moniliasis in the literature do not conform to the consistent pattern observed in the present series of cases.

Robertson,[75] in discussing a case of supposed moniliasis, refutes the work of Cas-

tellani and the Flinns noting that, although the Monilia isolated from the sputum of his patient produced lesions in rabbits, no organism was cultured from bronchoscopic swabs or from pulmonary cavities of the patient. He expresses doubt that primary pulmonary moniliasis really exists, and his opinion is echoed by Good[45] in a review of specific fungus diseases of the lungs. Both workers feel that the role of Candida albicans in disease is limited to that of a secondary invader.

Histoplasmosis. In recent years, there has been widespread interest in the high correlation of pulmonary calcification and positive skin reactions to histoplasmin antigen, particularly in residents of the lower Mississippi basin.[41,71,80,90,94] For a long period of time the existence of a benign form of histoplasmosis was not appreciated, and it is only recently that the occurrence of the disease in epidemic form has been recognized.

Cases have been reported in Army personnel cleaning out dusty and abandoned barns and homes by Idstrom and Rosenberg,[58] in soldiers spending a night in an abandoned storm cellar by Cain, Devins and Downing,[9] in a group of men exposed to pigeon excreta by Feldman and Sabin[33] and Felson, Jones and Ulrich,[35] in a group of treasure seekers excavating the floor of a cave by Washburn, Tuohy and Davis[89] and Halliday,[47] in members of a farm family by Loosli and associates,[64] and in bridge scrapers by Englert and Phillips.[28]

A very high incidence of disease was found in the exposed personnel. Following an incubation period, an acute illness characterized by fever, chills, malaise, cough, weight loss, chest pain and fatigability occurred. Chest roentgenograms revealed diffuse pulmonary lesions quite similar to those seen in cases of farmer's lung, although hilar lymphadenopathy was sometimes encountered in histoplasmosis. The diagnosis in most of the epidemics reported remained obscure until the passage of time revealed calcification of the pulmonary lesions and positive histoplasmin skin tests, as well as culture of H. capsulatum from environs in which the disease had originally been contracted. Schwartz and Spitz[78] and Furcolow and Grayston[42] have reviewed the epidemics in detail, presenting incontrovertible evidence that the organism H. capsulatum was responsible.

Despite many clinical similarities, dyspnea was never a marked feature in the cases of histoplasmosis, while in farmer's lung it is the paramount and most distressing symptom. Unlike histoplasmosis, none of the cases in the present series has shown late calcification of the pulmonary lesions, and skin tests with histoplasmin have been uniformly negative. In addition, Feldman and Sabin[33] describe the pulmonary lesion of histoplasmosis as a caseating granuloma in a case autopsied after death due to coronary disease. This would seem to be the logical precursor to the calcified lesions later encountered. In Case XXVI, however, the lesion of farmer's lung is seen to be noncaseating granuloma, and this is substantiated by the experiences of Dickie[21] and Lawton.[61] Lastly, the present series of cases has occurred in a geographic zone north of that in which histoplasmin reactors are commonly found. Current evidence would seem to exclude any possibility of histoplasmosis as the etiologic agent in farmer's lung.

Other Specific Fungus Infections. The cases presented conform to no known specific fungus infection and are unlike those cases of acute blastomycosis described by Bonoff[3] or of torulosis as presented by Greening and Menville.[46] Skin testing with blastomycin was negative, as were tests with coccidioidin. The latter was unlikely in any case due to the far removal from the endemic area of coccidioidomycosis in the southwest.

Pulmonary aspergillosis as described by several authors[15,20,43,50,76] does not follow a clinical or roentgenologic pattern suggestive of farmer's lung despite the association of many cases of aspergillosis with grain, hay or fowl. Late in the last century, it was considered an occupational disease of persons who mixed grain and water in their mouths and forced the mixture directly in-

to the beaks of pigeons to fatten them. Wig makers, sponge beaters, feed mill workers and even threshers have been listed as subject to aspergillus infection. In many cases, however, the question as to whether the organism is a primary pathogen or a secondary invader is unsettled. Pulmonary cavitation and pleural reaction are described, however, in contrast to farmer's lung, where such reactions have not been observed. In addition, skin testing with aspergillin has been uniformly negative in the present series of cases.

If a true fungus infection were at fault, some reaction to the antigens used for skin testing in these cases might have occurred, however slight, for Emmons, Olson and Eldridge[27] have pointed out the cross reactions involved in the mycoses, particularly between histoplasmin, blastomycin, coccidioidin and haplosporangin. No positive reactions, however, other than those expected with the antigen of C. albicans occurred. Present evidence weighs heavily against an infectious agent as the cause of farmer's lung.

Sarcoidosis. As previously noted, the roentgenographic distinction of pulmonary sarcoidosis from farmer's lung may be impossible, although the presence of hilar or mediastinal lymphadenopathy is strongly in favor of the former diagnosis. Oblath and associates,[69] in a discussion of pulmonary moniliasis, present 6 cases diagnosed as pulmonary fungus infection and stress the difficulty in separating fungus infection from sarcoid disease, raising the question of similar etiologic backgrounds. Törnell[87] similarly questioned the possibility of sarcoidosis representing a fungoid disease. In his opinion the vegetable dusts are innocuous unless contaminated by fungi or impurities, when inhalation, as by threshers, results in a bronchomycosis indistinguishable clinically, pathologically and roentgenologically from sarcoid disease. The cases presented in this series, however, have not been established as due to bronchomycosis.

Broch, Moe and Wehn,[5] in a discussion of pulmonary fibrosis, are of the opinion that Boeck's sarcoidosis represents an allergic reaction to various harmful agents. They stress the nonspecific changes on roentgenologic examination, stating, "The radiogram is by no means characteristic, but may resemble any form whatsoever of diffuse interstitial pulmonary fibrosis." If true, this broad and nonspecific classification would necessarily include farmer's lung as a type of sarcoid disease. Others, however, object to such sweeping generalizations.

In an authoritative discussion and classification of pulmonary fibrosis, Mallory[66] assigns 6 cases of long standing fibrosis accompanied by acute progressive lesions of granulomatous type as possible sarcoidosis, which, if true, might require some change in concept of the disease. King,[59] however, in discussing Mallory's work, objects to such a diagnosis in the absence of additional lesions of the skin, peripheral or mediastinal lymph nodes, bones, eyes, parotids, or spleen.

An exhaustive review of the literature and investigation of 160 cases of sarcoidosis, as presented by Longcope and Freiman,[63] points out the fallacy of relying too heavily on the type of tissue reaction as being specific for sarcoid disease, since the tubercle bacillus, beryllium and silica are capable of eliciting responses which closely resemble it. They point out the erratic and unpredictable course of sarcoidosis with its remissions and exacerbations, as well as the wide variety of symptoms and objective findings.

In contrast, farmer's lung has but few variations in regard to exposure, onset and clinical course. The roentgenologic findings are consistently uniform, and there has been no evidence of involvement of other structures than the lung parenchyma. Farmer's lung stands clearly apart from sarcoidosis as it is known clinically at this time.

Other Syndromes. Farmer's lung is distinguished from the acute diffuse interstitial fibrosis described by Hamman and Rich[49] by the clinical history of exposure in the former and improvement after removal from the environment initiating the pulmo-

nary pathology. In addition, the pathology of the Hamman-Rich syndrome apparently does not involve a granulomatous type of reaction.

In bronchiolitis fibrosa obliterans as described by La Due,[60] a specific noxious agent, either chemical, infectious or idiopathic, results in injury and destruction of the bronchiole with resultant organization of exudate. Although representative of a type of pathology seen in silo-filler's disease, there is no pathologic similarity to farmer's lung, and certainly the important factor of sensitization does not occur as it does in the latter disease.

TREATMENT

Prophylactic means of avoiding inhalation of all organic dusts of the kinds mentioned would be the only effective method of preventing the disease and would depend upon wide dissemination of knowledge concerning the dangers of such inhalation as well as the usefulness of masks, respirators, and barn fans. Meticulous avoidance of storing wet hay and grain would be an important factor in preventive therapy also.

Once the disease process is established, removal of the patient from the farm environment is indicated. Oxygen may be used to aid in relieving dyspnea, and iodides have been found helpful in many cases. Steroid therapy is recommended by Dickie,[21] who feels that it may be of aid in preventing some of the fibrosis which occurs. Antihistaminics have produced no noticeable response when employed, and in 1 patient (Case XIX) an autogenous vaccine prepared from sputum cultures was of no benefit.

Following the acute phase, establishment of sensitization has required occupational adjustments to an extent ranging from complete removal from the farm environment to varying degrees of restriction of farming activities.

In the chronic phase leaving the farm environment is considered essential and some improvement may ensue even in the presence of severe disability. Additional therapy is entirely symptomatic and supportive.

REPORT OF CASES

The following cases have been selected for presentation in detail to illustrate variations in the mode of onset, clinical course, and later stages of the disease process.

CASE IX. E.K., a thirty-seven year old male, was admitted to the hospital in November, 1955, with complaints of cough starting on the day of admission and dyspnea which had increased steadily in severity for a little more than two weeks. In late October, he had cleaned out moldy silage, inhaling quantities of dust, but was asymptomatic until early the following month, when he experienced chills and became short of breath.

The patient had spent his early childhood on a farm and though a factory worker in later years, he worked summers at farming. In 1954, he bought a farm and began dividing his time between it and his factory job. There was no history of allergy or other significant illnesses.

During most of the two months' hospitalization, the patient was critically ill. Dyspnea increased, and he was cyanotic without oxygen. A daily spiking temperature reached 104° F. the first two weeks, 102° F. the next two weeks, then 101° F. for almost two more weeks, finally returning to normal. A weight loss of 33 pounds occurred.

On admission, the white blood cell count was 21,200 with a differential of 73 per cent segmented cells, 8 per cent band forms, 14 per cent lymphocytes and 5 per cent monocytes. The red blood cell count was 4.42 million with 14 gm. of hemoglobin. The urinalysis was normal, the nonprotein nitrogen 38.5 mg. per cent, the sedimentation rate 64 mm./hour. Sputum smears and cultures were essentially negative. The electrocardiogram revealed an abnormal tracing with increased right heart load suggested. A chest roentgenogram on November 21, 1955 showed quite diffuse granular infiltrates throughout the lung fields with emphysema of the peripheral bases (Fig. 5). By December 5, 1955 the disease process had progressed to the point where hazy confluent and patchy zones of infiltration obscured large areas of both lung fields, but with the apices and bases remaining

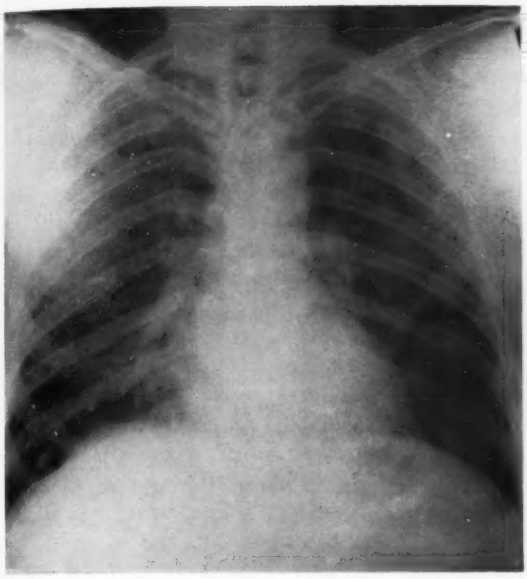

Fig. 5. Case IX. Admission chest roentgenogram on November 21, 1955. Widespread rather hazy and finely nodular infiltrations with emphysema of peripheral bases. Mild coarsening of truncal markings.

Fig. 6. Case IX. Two weeks later, on December 5, 1955. Marked progression of disease with coalescence and enlargement of pulmonary lesions. Large areas of lung obscured by patchy zones of infiltration. Apices and bases fairly well aerated. Severe dyspnea present clinically.

fairly well aerated (Fig. 6). The patient at this time was extremely dyspneic.

A variety of antibiotics appeared to produce little clinical change, but immediate improvement followed the administration of potassium iodide. The blood cell count and sedimentation rate returned to normal, and progress chest roentgenograms demonstrated slow clearing of the widespread lesions. By February 27, 1956 the lung fields were almost normal in appearance with only suggestion of some residual linear streaking in the bases (Fig. 7).

The patient has been asymptomatic since his illness, but he has not entered the barn since discharge from the hospital. He has returned to his factory work and has a hired man to do all the farm chores. On March 9, 1956 the vital capacity was normal (91 per cent), and he denied exertional dyspnea. A mildly positive skin test for C. albicans was observed, but no organisms had been isolated from the sputum during his illness. Other skin tests were negative. An electrocardiogram on June 21, 1956 revealed borderline abnormality with equivocal evidence of right heart strain. However, considerable improvement over the electrocardiogram of December 14, 1955 was manifested.

Comment. Symptoms developed in this case after what appeared to be a single heavy exposure, and he was one of 3, in this group of 11 cases, who reported a delay of one or two weeks between the exposure

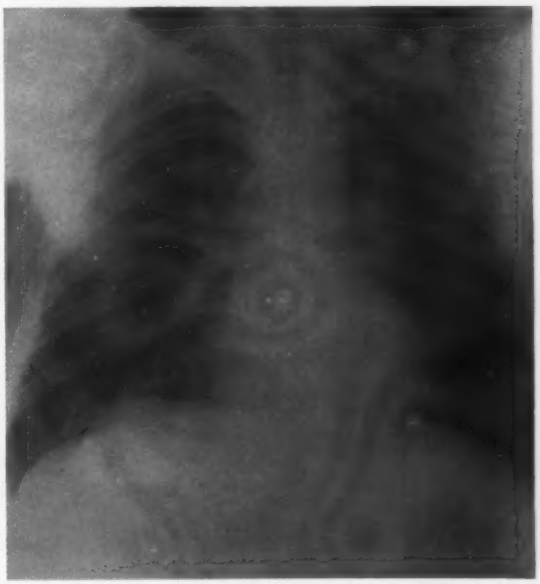

Fig. 7. Case IX. Follow-up examination February 27, 1956. Clearing of widespread acute pulmonary lesions. Roentgenographic changes lagged behind symptomatic improvement.

and onset of clinical symptoms. Although the history of these 3 cases suggests an incubation period, their clinical courses and symptoms parallel the others in the group, and the true cause of this variation is one of the many unanswered questions regarding this disease. These few exceptions, however, are not felt to give strong support to the presence of pulmonary infection due to an unidentified organism, and it is suspected that variability in onset of sensitization is more likely responsible.

CASE II. L.B., a twenty-five year old white male, was admitted to the hospital on April 9, 1952 with complaints of severe dyspnea, fever and drenching sweats.

Born and raised on a farm, his past medical history was negative for allergies or other significant illness. In the fall of 1951, a large amount of hay was put up to provide for 140 head of stock. Much of it was put into the mow loose, while the rest was baled and either stored in a shed or stacked in the open. Most of the latter became very moldy and was fed to the young stock. Large quantities of white powdery dust were inhaled repeatedly in the handling of this moldy hay, and vigorous manipulation was needed to break up the bales, occasionally requiring use of an axe.

In addition, late in December, 1951, he "cleaned off" the top of one of the silos of especially moldy silage and reported the "steam" produced some coughing. Early in January, 1952, the patient felt he was developing a "cold" in his lungs. Dyspnea occurred and increased in severity, and there was a severe unproductive cough with sweating, fatigue and lassitude.

He was treated as an out patient with penicillin and sulfa drugs. Improvement occurred at bed rest but on attempting to help with the chores in the barn immediate onset of coughing and dyspnea occurred. This state of affairs continued until admission to the hospital, by which time symptoms were severe and there had been a weight loss of 65 pounds (the original weight of 220 was due to his large size and heavy build, not to obesity). The temperature fluctuated markedly, reaching 105° F. on one occasion. Although the white blood cell count was unremarkable, the red blood cell count was 6.25 million and the hemoglobin 18 gm.

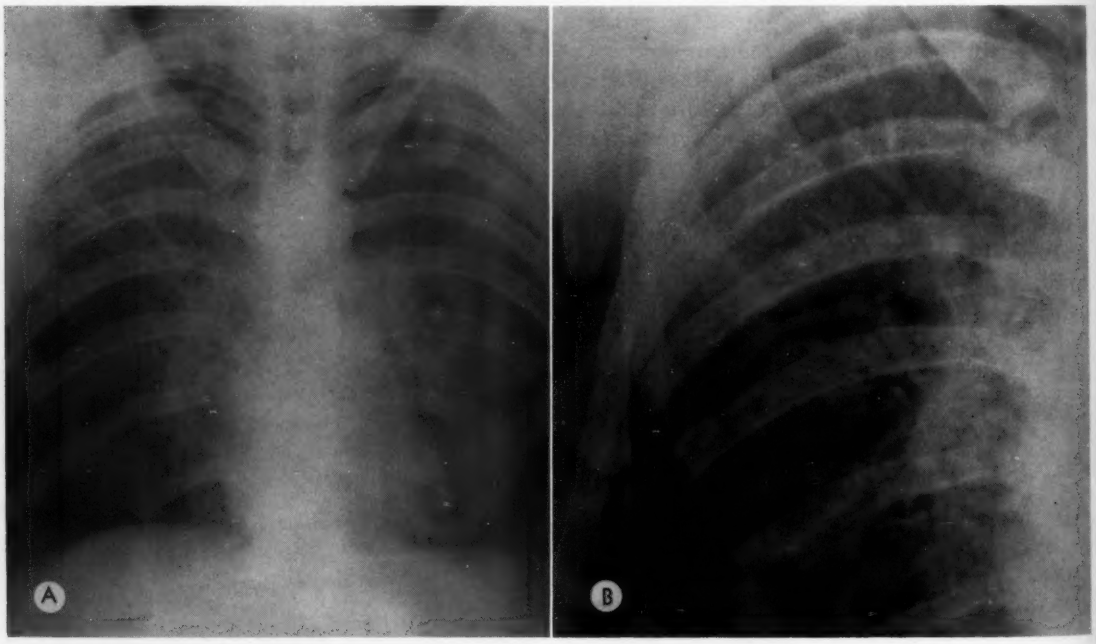

FIG. 8. Case II. (*A*) April 15, 1952. Scattered nodules of varying size, somewhat more prominent on the right with coarsened truncal markings but relatively clear apices and bases. (Fissure for azygos lobe on the right.) Onset of symptoms over three months previously with continued intermittent exposure to moldy hay dust. (*B*) Close-up of right lung. The coarsely granular and nodular character of the widespread lesions is apparent in a rather severe case of the disease.

(113 per cent). Smears and cultures of the sputum were reported negative for fungi on four occasions, and agglutination tests for typhoid, paratyphoid, Proteus OX19 and Brucella were negative. Tuberculin skin tests, first and second strengths, were reported negative.

A routine miniature chest roentgenogram was reported on admission as unremarkable, perhaps due in part to the inherent limitations of this method of examination, but also believed due to the relatively rapid change in appearances of the pulmonary pathology in this particular case. On April 15, 1952, only six days later, a standard 14 by 17 inch chest roentgenogram demonstrated scattered coarse nodular infiltrates, somewhat more prominent on the right with the apices and bases comparatively clear (Fig. 8*A*). A closeup of the right lung field demonstrated the coarse granular character of the lesions to somewhat better advantage (Fig. 8*B*).

The patient improved rapidly, and on April 21, 1952 there had already been definite decrease in the size and number of the scattered lesions (Fig. 9). By May 28, 1952 marked clearing had occurred with only mild residual granular coarsening of the truncal markings (Fig. 10).

For a short time he did well but in late June, while helping with haying he was exposed to dust, and dyspnea and fever recurred. Symptoms progressed and in three weeks he reentered the hospital. On this admission, administration of iodides produced immediate improvement and he was released in a week's time. Following discharge he took a number of different jobs, none of which involved farming, and it is of interest that on one of these he was exposed to large quantities of dust caused by shredding crepe paper without recurrence of symptoms. However, about one year later, on returning to the farm to "help out" for a week, he experienced recurrence of fever, cough and dyspnea. Since this episode he has avoided all farm work and has been well, although he claims some impairment of exertional capacity. The vital capacity in March, 1956, however, was above normal and a chest roentgenogram on that date was normal.

Comment. This case represents a typical example of one of the three arbitrary divisions made in regard to mode of onset, and 9 of the cases reviewed fell into this group.

Fig. 9. Case 11. April 21, 1952. Despite the short interval of six days there has been some decrease in the size and number of the lesions which now appear more discrete.

All experienced more or less gradual onset of symptoms following a period of exposure to unusually dusty conditions associated with extremely moldy hay, silage, fodder,

Fig. 10. Case 11. May 28, 1952. Fairly rapid clearing of the pulmonary changes following hospitalization and complete removal from environmental factors on the farm responsible for the disease. Minimal residual coarsening of truncal markings.

FIG. 11. Case XXVI. Chest roentgenogram of March 30, 1953. Widespread finely granular infiltrates associated with prominent lung markings. Changes relatively mild for six months' duration of symptoms.

etc. A single exception (Case XXIV) occurred after months of grinding fresh hay with a hammer-mill, during which time he inhaled large quantities of fine particulate matter definitely not moldy. With the onset of his symptoms, however, sensitivity to the barn and silo developed.

All members of this group would appear to represent cases of gradual sensitization to the inciting agent involved with eventual development of clinical symptoms.

CASE XXVI. E.W., a forty-three year old white male, had been born and raised on a farm and had no known allergies. At the age of seventeen, and for the following five or six years, however, he had experienced cold drenching sweats with chills and fever on "opening" the silo in the fall (usually in October). Headaches and severe dyspnea also occurred. The symptoms subsided after a couple of days, but because of these attacks he stopped "opening" the silo at the age of twenty-two or twenty-three, leaving such work to others. He continued to farm, however, without further trouble until 1952.

In August of that year, the patient developed a cough productive of large quantities of greenish sputum and in October experienced onset of dyspnea which increased steadily in severity. This followed the breaking up of an old cement floor in the barn, although the patient did not think the amount of dust involved in the procedure was exceptional. The dyspnea became very severe, and by February, 1953, he was actually orthopneic. During this period, he lost 20 pounds in weight and noted definite aggravation of dyspnea on entering the barn.

The patient was studied extensively elsewhere, and a wide variety of laboratory tests was reported within normal limits, including urinalysis, blood cell counts, sedimentation rate, serology, serum proteins, agglutination test for brucellosis, the basal metabolic rate, an electrocardiogram, and a roentgenogram of the right hand. A duodenal ulcer was found on examination of the upper gastrointestinal tract (this apparently was responsible for only mild symptoms and responded rapidly to dietary management). A reduced vital capacity characteristic of obstructive phenomena in the lungs was also reported.

A chest roentgenogram dated March 30, 1953 revealed a diffuse finely granular interstitial infiltration associated with coarsening of the truncal markings (Fig. 11). Review of films taken during the first few months of 1953 demonstrated gradual increase in severity of the process during this time.

Bronchoscopic examination and microscopic examination of bronchial washings were reported negative, and on May 5, 1953 a wedge biopsy of the tip of the lingula of the left upper lobe was performed at the Mayo Clinic, Rochester, Minnesota. Microscopic examination of the excised tissue revealed noncaseating granulomata considered compatible with the lesions of sarcoidosis (Fig. 3, *A* and *B*).

Cortisone was administered and the patient improved. A chest roentgenogram in June, 1953, demonstrated clearing of the diffuse lesions and the patient felt well that summer. In November, 1953, a slight recurrence of symptoms was experienced when working in the closed barn. Since, he has avoided all dusts and as much barn work as possible. His farming activities have been curtailed, and he now works a smaller farm.

When seen in March, 1956, the patient estimated his capacity for work had been diminished almost 50 per cent. The vital ca-

pacity was 3.6 liters (80 per cent), the blood cell count normal except for a slightly reduced hemoglobin (13.2 gm.). An electrocardiogram revealed moderate abnormality suggestive of chronic cor pulmonale with secondary coronary insufficiency. A chest roentgenogram on March 29, 1956 showed essentially clear lung fields. The heart was small and vertical in position, and the left sulcus was blunted, undoubtedly due to slight pleural thickening following the thoracotomy for biopsy purposes in 1953 (Fig. 12).

Comment. The clinical history of this case strongly indicates that he is 1 of the 7 cases developing severe signs and symptoms of the syndrome because of sensitization due to repeated mild episodes. Here, many years separated the original series of exposures and the final development of the full blown clinical and roentgenographic picture.

The possibility of sarcoidosis was questioned, for as pointed out by Longcope and Freiman[63] the tissue reaction of that disease is mimicked by numerous other agents, and the diagnosis requires careful correlation of clinical and pathologic findings. Woolner,[91] of the Mayo Clinic, agrees, for although he feels that the histology of this case is typical of sarcoidosis, he is also of the opinion that other agents could cause a similar or identical noncaseous granuloma. Furthermore, he regards sarcoidosis as a diagnosis of exclusion.

The section has been reviewed also by Freiman[39] who states, "The lesion is basically a chronic interstitial pneumonitis in which granulomas have developed." He felt it reminiscent of the cases occurring in beryllium workers and commented in addition, "Pulmonary sarcoidosis rarely shows this much interstitial infiltration in those portions of the lung between the granulomas. I suspect that the appearance is similar to that seen in the other cases of 'farmer's lung' but with the addition of focal granulomatous change."

As previously noted, this case is felt to represent a comparatively early stage in the pathologic course of the disease. Despite this, the patient has had to restrict his farming activities radically and complains of permanent residual disability.

Fig. 12. Case xxvi. Essentially clear lung fields on March 29, 1956, although exertional capacity limited. Farming activities have had to be restricted severely. Blunting of left sulcus apparently followed lung biopsy.

Case iii. A.D., a fifty-six year old male, was admitted to the hospital on November 9, 1952 with multiple complaints, including severe dyspnea, chills, fever, weakness, muscle aching and a productive cough.

For over six years he had suffered a chronic productive cough in the winter time aggravated when working with corn silage. Gradually his wife had had to assume all chores involving such silage because of his reaction to it.

The acute illness began one month before admission with gradual onset and aggravation of the symptoms mentioned. Anorexia and a 10 pound weight loss also occurred during this period.

On admission, the temperature was 101.2° F., and he continued to run a low-grade temperature during his hospitalization. The pertinent physical findings consisted of rales and wheezes throughout the lung fields and definite clubbing and cyanosis of the nails. The white blood cell count was 21,000 with 79 per cent polymorphs, 15 per cent lymphocytes, 5 per cent monocytes,

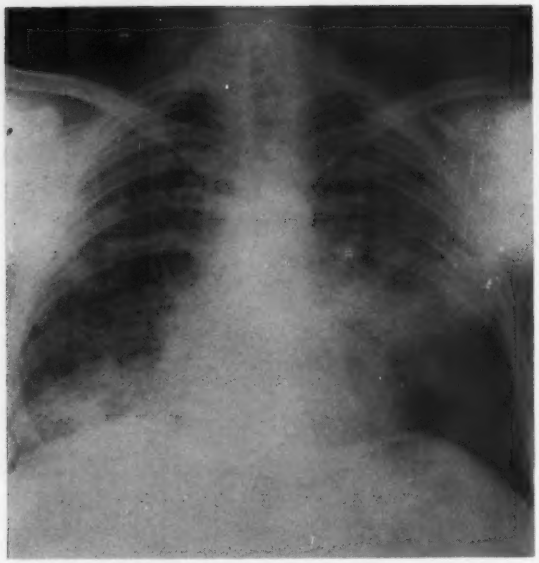

Fig. 13. Case III. Chest roentgenogram of November 10, 1952. Irregular stringy infiltrations with curved zone of conglomerate opacity extending across the lower left lung field. Coarse granular infiltrations, particularly on the right. Death due to nephritis. Autopsy revealed diffuse interstitial fibrosis with some granulomata. A rather advanced, but still active, case of the disease.

and 1 per cent eosinophils. The hemoglobin was 12.4 gm. Repeated urinalyses revealed albumin in appreciable quantities as well as red and white blood cells and waxy and hyaline casts. The specific gravity was fixed, never rising above 1.009. The sedimentation rate was 62 mm./hour, and the nonprotein nitrogen 135 mg. per cent. Six sputum cultures during his hospitalization were reported positive for Candida albicans.

Roentgenographic examination of the chest on November 10, 1952 revealed stringy and granular infiltrations of both lung fields with a rather conglomerate appearing arc-like zone of consolidation extending across the lower left lung field (Fig. 13). The coarse granular character of the widespread lesions suggested the reaction to moldy hay and grain as seen in farm workers (which at that time was assumed to represent a true pulmonary mycosis), and the history of sensitivity to silage was then elicited.

Antibiotics (penicillin, aureomycin, terramycin) and potassium iodide produced no significant change. Diuretics and intravenous fluids failed to lower the nonprotein nitrogen appreciably, and the urinary findings persisted. On November 24, 1952, the patient died.

At autopsy, the lungs were "stiffened" and contained many 5–8 mm. lesions having the gross appearance of granulomata. In addition, parenchymal fibrosis was apparent on cut section, particularly of the upper lobes. Originally regarded as a nonspecific subacute granulomatous process by the pathologist who performed the autopsy, it is now felt this case represents a relatively far advanced stage of the disease. Lung sections revealed extensive interstitial fibrosis with a few focal granulomata (Fig. 4).

Sections of the kidneys demonstrated a relatively acute nephritis and evidence suggesting some degree of chronic disease.

Comment. This patient represents the group of 7 developing symptoms apparently due to sensitization associated with previous mild episodes. Although the lungs demonstrated a rather severe degree of interstitial fibrosis, as would be expected after several years of such exposure and symptoms, the cause of death was apparently due to nephritis and not the pulmonary disease. The residuum of the granulomatous reaction and the collagen present indicate the active nature of the lesion although relatively far advanced in contrast to Case XXVI.

Case XVI. O.M., a fifty-one year old female, the wife of a farmer, cleaned out a mow of rotten moldy hay in January, 1952, while her husband was ill. Large quantities of moldy dust were inhaled, and about two weeks later she developed a "cold" with severe shortness of breath and cough. Although symptoms persisted, she did not consult her physician until April. At that time, there was a severe cough productive of greenish sputum, and she was severely dyspneic. Fine rales were scattered throughout the chest, but no other significant physical findings were reported.

A sputum culture grew a yeast-like fungus with mycelia, identified as Endomyces. A chest roentgenogram on April 10, 1952 demonstrated generalized finely granular mottling throughout the lung fields (Fig. 14). It was because of this appearance and the diagnosis suggested that the history of exposure was elicited. Symptoms improved rapidly on administration of an iodine containing drug, but mild subjective limitation of exertion has persisted to date. More important, sensitization to the barn atmosphere was

established, and the patient becomes dyspneic on entering the barn. She therefore tries to avoid chores involving such exposure, although she milks a few cows daily to aid her husband. This, however, is always associated with mild symptoms.

When seen in March, 1956, no significant physical findings were elicited. The chest roentgenogram was unremarkable with only a suggestion of nonspecific accentuation of truncal markings. The blood cell count was normal. Skin testing with monilia antigen produced a marked reaction (graded 4+), and other skin tests were negative. The vital capacity was 85 per cent (low normal).

Comment. This case is of particular interest for two reasons: her sex and the delay in onset of symptoms after a single massive exposure. The latter phenomenon is unexplained in the few cases in which it occurred.

Two women with the disease were encountered in this series of cases. Both developed symptoms after exposure to moldy dusts involved in farm chores. As would be expected, they have been able to control, better than the men, the extent of subsequent exposure and, therefore, the degree of disability. Both women have curtailed severely their activities in the barn, and although both complain of some limitation of exertional capacity, they have demonstrated no gross impairment of vital capacity despite continued residence on the farm. The continued exposure of Case XVI, however short it may be each day, is felt to entail some risk of progressive disease as it is associated with recurrent symptoms.

Case V. F.F., a fifty-three year old white male whose activities have been confined to farming all his life, reported no history of allergy and stated that "flu" incurred during World War I had been his only significant previous illness.

The fall season of 1951 was wet, and an accumulation of oats was allowed to stand on his farm for a few weeks. The damp grain became moldy and was shoveled out by the patient one afternoon. Symptoms occurred that evening, consisting of chest pain, dyspnea, cough and questionable fever. Recovery was rapid, and although improvement was marked he did not

Fig. 14. Case XVI. One of the two women encountered in the series. Chest roentgenogram of April 10, 1952, three months after onset of symptoms following exposure to moldy hay dust. Diffuse granular mottling typical of farmer's lung. So-called "sand storm" appearance visible in some areas on original roentgenogram.

feel he returned to his normal state of well-being. In addition, he complained of exposure to unusually large amounts of dust that fall and early winter, and in January, 1952, he became severely ill, necessitating hospitalization.

Dypsnea and cough were severe. A spiking temperature on one occasion reached 106° F. Drenching night sweats occurred, and the sweat was reported as yellow and malodorous. He lost 45 pounds in weight and experienced extreme weakness. A urinalysis was normal, and the white blood cell count was 12,900 with a normal differential. The red blood cell count was 5.58 million, but the hemoglobin was only 13.9 gm. (89.7 per cent). The sedimentation rate was 20 mm./hour, and a sputum culture was reported as negative.

A chest roentgenogram on March 21, 1952 revealed fine irregular granular and nodular infiltrates in the lung fields. The peripheral bases, particularly the left, were clear (Fig. 15).

Aureomycin and potassium iodide were administered during his stay in the hospital with apparent improvement. On discharge, however, he noted shortness of breath on exertion, par-

FIG. 15. Case v. Chest roentgenogram of March 21, 1952. Relatively small diffuse infiltrates typical of farmer's lung. Peripheral bases appear emphysematous. Symptoms severe at this time. Original exposure to dust from moldy oats.

ticularly in the barn, and had to rest between the slightest tasks.

The patient continued to farm, and symptoms persisted. In February, 1954, he was studied at the University Hospitals, Madison, Wisconsin. The red blood cell count was reported as 5.6 million and the hemoglobin 17.9 gm. All blood chemistry determinations were normal (nonprotein nitrogen, carbon dioxide combining power and serum chlorides). The acid and alkaline phosphatase studies were normal and the serology negative. The total serum protein was 8.4 gm., 4.1 gm. albumin, 4.3 gm. globulin. Five sputum examinations were negative for malignant cells or for fungi on smear and culture.

A chest roentgenogram was interpreted as showing chronic inflammatory changes in the right lower and probably the right middle lobes, suspected of being due to bronchiectasis. A bronchogram, however, was negative. Interstitial pneumonitis was also believed present.

On admission, the vital capacity had been 47 per cent. On administration of iodides the patient improved, and after two weeks the vital capacity measured 71 per cent of normal. A diagnosis of chronic interstitial pneumonitis was made, and the patient advised to avoid all exposure to grain, dust, molds and the like.

For economic reasons, the patient has been unable to give up farming and symptoms have persisted and increased. His wife now handles much of the hay, and he hires the top of the silo "cleaned off." Nevertheless, he must do much of the barn work despite severe dyspnea on the slightest exertion. A respirator has failed to help, for he cannot tolerate one, not being able to "get enough air through it." Although somewhat better in summer than winter, he is never symptom-free and at present is dyspneic even at rest with cyanosis of the nail beds and lips and well marked clubbing of the nails.

In March, 1956, the white blood cell count was normal, but the hemoglobin was 18.6 gm. (120 per cent). An electrocardiogram revealed marked abnormality with first degree atrioventricular block and typical "p pulmonale." Right ventricular hypertrophy was manifested, and the changes were considered compatible with fairly advanced chronic cor pulmonale.

A chest roentgenogram on March 13, 1956 demonstrated mild increase in the transverse cardiac diameter since 1952. Only minimal residual of the fine granular mottling originally present was observed although there was diffuse coarsening of the truncal markings felt to represent a chronic interstitial pneumonitis with progressive parenchymal fibrosis. The roentgenographic changes are mild for the severe degree of functional impairment (Fig. 16).

Comment. This case is representative of the largest group of the series in regard to onset of the disease following a single marked exposure to grain dusts or dusts of moldy hay, silage or shredded corn. Eight of this group of 11 cases reported onset of symptoms within hours of exposure. No incubation period, therefore, was involved, and allergy would seem improbable as the explanation for this initial reaction. Later sensitization to the spore laden air of the barn and silo occurred in this case, as in others, however, with aggravation of symptoms on later exposure.

This group of cases would seem to indicate that in many the initial reaction is due to pulmonary reaction to inhaled particulate matter of organic nature with later sensitization to this material. Continued

exposure, as in this case, leads to progressive pulmonary disability which is considered largely irreversible.

Case xxiii. C.T., at the age of twenty, in 1927, experienced an episode of severe dyspnea after cleaning out moldy ensilage. He recalls being confined to bed for a week and although he recovered he noticed subsequently that he became short of breath when in the barn. Because of this he avoided farm work as much as possible, particularly in the winter time, when he worked in the woods logging, leaving the farm chores to his father.

In 1950, however, the patient's father died, and as the only son he was forced to assume all the duties of the farm. Exposure to the barn atmosphere necessarily occurred and symptoms increased. He did fairly well, however, until the two year period prior to his examination in 1956, during which time this forty-nine year old male noted marked increase in exertional dyspnea later associated with a morning cough productive of one-fourth to one-half of a cup of sputum. There had been no hemoptysis, but a weight loss of 30 pounds had occurred.

Fig. 16. Case v. Follow-up roentgenogram of March 13, 1956. Minimal residue of granular appearing infiltrations but diffuse coarsening of truncal markings considered compatible with chronic interstitial pneumonitis. Patient has continued farming despite severe symptoms. Note increase in heart volume since 1952.

Fig. 17. Case xxiii. Extensive chronic pulmonary fibrosis with compensatory emphysema and probable bronchiectasis. Long-standing history of sensitivity to barn atmosphere. Regarded as the end stage of the disease process.

Due to the productive cough and weight loss he was institutionalized in February, 1956, on suspicion of tuberculosis. The tuberculin skin test, however, was negative as were repeated smears and cultures of the sputum for the tubercle bacillus. On three occasions, sputum cultures were positive for Candida albicans, and an intradermal test with monilia antigen was mildly positive (graded 2+).

A chest roentgenogram on March 19, 1956 revealed no change from earlier studies in December, 1955, and February, 1956. Extensive bilateral pulmonary fibrosis was apparent associated with compensatory emphysema and, undoubtedly, extensive bronchiectasis (Fig. 17). No earlier films were available as medical help had not been sought until late in the stage of his disease.

In addition to emaciation, clubbing of the nails occurred. The vital capacity was 1.6 liters (38 per cent) and an electrocardiogram revealed suggestive, but not diagnostic, evidence of right ventricular strain. Routine laboratory work was unremarkable. During his stay in the sanatorium, some subjective relief of dyspnea was reported, and the patient gained 16 pounds in weight. On discharge, however, he returned to the farm environment because of economic necessity and inability to turn to any other vocation.

Comment. This patient presents the longest history of any case in the series and is felt to represent the end stage of the disease process—extensive pulmonary fibrosis. Bronchiectasis is undoubtedly present, and Candida albicans may well be a superimposed infectious agent. The latter, however, is not considered of likely clinical significance.

The many years of residence on the farm were apparently possible only because of the patient's partial removal from occupational hazards up to the time of his father's death. Even then, on returning to the barn chores, he did fairly well until symptoms progressed rapidly during the past two years.

Although some symptomatic relief occurred on removal from the farm environment, permanent changes are severe. Furthermore, it is anticipated that he will experience rapid recurrence of symptoms and progressive disability on returning to the farm. The prognosis is considered poor.

DISCUSSION

Although the etiologic factors remain somewhat obscure, the syndrome known as farmer's lung stands out as a sharply demarcated entity. The course of the disease would appear to be dependent upon two different elemental reactions which differ in many respects from better known disease processes following these two channels. The first of these represents pulmonary reaction to inhaled organic material, the second a form of allergic reaction to such material.

To regard farmer's lung as a form of pulmonary mycosis is no longer tenable. Certainly no fungus known today has been identified as the cause of the disease, and the onset of symptoms within hours of exposure in many of the cases would discount the possibility of an infectious agent being responsible for the disease. The possibility of a fungus acting as a secondary invader cannot be entirely excluded, but the presence of such organisms as Candida albicans in the sputa of a wide variety of patients would indicate that even such a possibility is unlikely.

The pneumoconioses developing after exposure to inorganic dusts have been studied and reported extensively. This has been particularly true of silicosis in view of the disability involved in that disease and its direct relationship to occupation. Pulmonary reaction to inhalation of organic dusts, however, has received but little notice, and the scattered reports concerned with the subject are devoted to unique occupational or industrial problems. Such disease states, however, are justifiably termed pneumoconioses also, for the word simply means lung reaction to dust.

Shanks and Kerley[79] point out that pneumonoconiosis (or pneumoconiosis) refers to lesions due to dust inhalation, whereas, "There is no similar descriptive term for diseases due to inhalation of fumes, organic fibers and fungi, or other organisms specific to certain occupations." The same authors point out, "There is probably no such thing as a harmless dust if it is inhaled in large enough quantites for long enough." They feel, however, that the resultant impairment of pulmonary elasticity is simply a mechanical effect of the foreign material. However, von Rüttner and Stofer[77] report a case of progressive pulmonary disability in a retired miller exposed for many years previously to wheat dust. Roentgenologic studies showed gross fibrotic infiltration, and autopsy demonstrated wheat dust in pulmonary granulations on microscopic study under polarized light.

That the inhalation of organic dusts may produce a pulmonary granulomatous reaction has been shown by the experimental work of Zettergren.[93] In studying the problems involved in thresher's lung, a group of rabbits was exposed to sterile grain dust (from rye and oats), and another set of animals to similar dust inoculated with monilia. Five days after exposure the sterile dust had resulted in the formation of small (seldom over 400 μ) interstitial granulomata which Zettergren termed "dust gran-

ulomata." Giant cells of a foreign body type were present, and these were described as containing dust particles. Occasional confluence of adjacent granulomata was observed.

Some of the animals exposed to the monilia-contaminated dust were sacrificed at five days, others at ten weeks. In the former, dust granulomata were observed and also what Zettergren termed "tuberculoid granulomata" containing epithelioid cells and surrounded by round cells which were mostly lymphocytes. These were larger, on the average, than the dust granulomata, and the largest ones often showed central caseation.

In the animals killed ten weeks after exposure to the monilia-contaminated dust, dust granulomata were not found, and the tuberculoid granulomata were less frequent and less typical. Some of these were caseated with a marked increase of connective tissue peripherally.

The fungus could be seen in sections and cultured from tissues in only a few animals, and Zettergren felt it did not proliferate *in vivo* but produced its effect through liberation of toxins on disintegration. Of some interest was the report of an increase in gamma globulin in the animals sacrificed at ten weeks, felt to represent an antibody formation evoked directly by the antigenic substances of the fungal cell.

Zettergren, therefore, has produced in rabbits a pulmonary granulomatous reaction to inhaled organic dusts, both sterile grain dust and grain dust contaminated with monilia. The variation in the appearance of the granulomata and the occurrence of caseation in some are not completely explained. In farmer's lung such variations occur, but caseation has not as yet been seen.

In contrast to the granulomatous reaction to organic dust, which can occur on initial exposure, the second fundamental reaction involved in farmer's lung appears to be allergic in nature and consists of immediate onset of symptoms, most often dyspnea, on the slightest exposure to the inciting agent, even if only the spore laden air of a closed barn. Relief occurs quickly on leaving the atmosphere invoking such a response. All but 1 of the patients reviewed complained of some degree of such sensitization, and the exception has never been re-exposed to farm dusts following his initial severe illness.

The relationship of fungi to asthma has been discussed by Bernton,[2] Cadham,[8] Flood,[38] and Hopkins, Benham and Kesten,[51] more than two decades ago. Brown,[6] in discussing the subject, points out the small size of the fungal spores which average only 3 to 5 micra in diameter, well below the 10 micra considered the critical size limit of particles able to reach the alveoli and produce silicosis. He also pointed out the small size of the fungal spore in relation to pollen grains.

Feinberg[32] discusses the importance of cross reactions due to related allergens among the fungi and comments on the high protein content of the spores. Peterson,[73] of the College of Agriculture of the University of Wisconsin, points out the limited knowledge of analyses of molds involved in hay and silage.

The type of allergy manifested in farmer's lung is not typically asthmatic in character, however, and involves difficulties in inspiration rather than expiration. Wheezing and rhonchi are rarely factors, and no response has been observed to antihistaminics. Furthermore, no cases of eosinophilia were seen, and no eosinophils have been reported in studies of the sputa.

Several disease states similar if not identical to farmer's lung have been described. Towey, Sweany and Huron[88] reported a group of cases developing symptoms after exposure to fungus spores in dust created by stripping the bark from maple logs which had lain on the ground because of cessation of work for a period of time during depression years. Although they considered the dyspnea as asthmatic in type, the roentgenologic and clinical findings otherwise

were identical with farmer's lung. The authors could not demonstrate a causative organism clinically and felt that their cases represented a local toxic reaction of unusual severity plus the added factor of sensitization, for they noted immediate distress when the patients returned to contaminated surroundings.

Bagasse disease of the lungs, also called bagassosis, and even bagasscosis, is similar in almost every respect to farmer's lung. Bagasse, the pulp of the sugar cane left after extraction of the juice, is baled and usually left in the field for months before being used to make insulating board. Moldy dust results from breaking the bales apart, and it is the workers so engaged who eventually develop shortness of breath, fever, chills, night sweats, weight loss, and roentgenologic changes similar to farmer's lung.

Sodeman and Pullen[82,83] and Sodeman[81] have presented a number of cases and obtained biopsy and autopsy material which they felt demonstrated a pulmonary fibroblastic reaction to foreign material seen under polarized light. This was thought to be particles of bagasse and to be the causative agent. They noted, however, the failure of workers exposed to the dust of the processed insulating board material to develop the disease, although the material was the same except for the absence of fungi, bacteria and allergenic protein due to the heat employed in processing. A questionable exception was a case reported by Sodeman as developing the disease after exposure to insulating board dust; however, this patient had previously been exposed to bagasse dust and presumably could have been sensitized.

Lemone and co-workers[62] reviewed the subject, elaborating on the roentgenologic changes, and stated they felt the process was reversible, with return to normal in five to six months. However, Castleden and Hamilton-Paterson[14] reviewed the problem of bagassosis in Great Britain and pointed out the presence of permanent changes in some cases. They felt the acute phase might be an allergic response but regarded the chronic process either as a type of silicosis, or a response to crystalline cellulose, or a chronic fibrotic process in tissues edematous from allergic response to antigen. Hunter and Perry[52] reported an autopsied case exposed to bagasse dust for over a year, several years prior to death. Fibrotic lungs and considerable bronchiectasis were found, processes they considered similar to any chronic interstitial pneumonia. They pointed out the close similarity of bagassosis to farmer's lung and also to byssinosis.

Animal experimentation by Gerstl, Tager and Marinaro[44] was felt to prove that the bagasse itself is a rather inert material, and that it is the microorganisms present which are responsible for the disease. Nevertheless, some pulmonary reaction to the intratracheal insufflation of the autoclaved material occurred.

Dusts arising from the industrial processing and use of cotton give rise to a number of syndromes[25] of which two resemble farmer's lung in some respects. Weaver's cough affects operatives handling mildewed yarn, and these workers develop progressive dyspnea, cough, aching and expectoration with relief twenty-four to forty-eight hours after removal from the environment. Byssinosis, on the other hand, represents chronic fibrosis and emphysema after long and continuous exposure to cotton dust. Although the eventual dyspnea and right heart strain are similar to late farmer's lung, the allergic factor would not appear to be as prominent.

Caminita and associates[10] have reviewed the literature in regard to the problem of cotton dust and discuss the various possibilities involved in producing the entities encountered. They note the heavy mold content of the dust and the frequent finding of monilia in patients' sputa, although no such organisms could be recovered from the dust itself. They felt, therefore, the fungi were secondary, not primary, pathogens.

That clinical syndromes similar to farmer's lung might occur in a wide variety of occupations and industries has been pointed out previously[24] and would seem

most likely in view of the widespread use of vegetable materials in industry and also the tendency for such materials to become moldy under certain conditions. At present, the disease is of greatest importance among farmers, particularly dairy farmers, and workers exposed to raw bagasse and to cotton dust.

CONCLUSIONS

1. Twenty seven cases of farmer's lung are reviewed, outlining the variations in onset and course.

2. Two fundamental reactions are considered to be involved in the disease process. There is an initial pulmonary response to inhalation of organic dusts involving a granulomatous reaction with associated interstitial fibrosis. Later sensitization to such dusts is believed to occur, and there is progressive pulmonary fibrosis on repeated exposures.

3. Some permanent pulmonary disability may follow the initial attack, and increasingly severe disability is certain to take place on repeated exposure, once sensitization has occurred.

4. The dusts involved are most often due to severely moldy hay, grain or silage, and the heavy fungal spore content of such dusts is believed largely responsible for the disease, although rarely the syndrome is due to vegetable dusts which are not significantly moldy.

5. The pulmonary reaction to the fungal spores is due to their action as inhaled foreign material and the disease is not believed to represent a pulmonary infection or mycosis.

6. In the majority of cases developing the disease, even if only a single attack, a change of occupation should be recommended strongly.

7. Preventive measures should be advocated widely in an effort to save the individual farmer from developing an economically disastrous disease.

8. A great deal is as yet unknown regarding the causation and mode of progression of farmer's lung, but present knowledge would seem to warrant regarding it as a form of pneumoconiosis due to organic dusts.

9. It is hoped the present work will stimulate experimental studies and clinical investigations into the many problems of this complex disease.

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ROENTGEN MANIFESTATIONS OF TORULOSIS (CRYPTOCOCCOSIS)*

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TORULA histolytica, known also as Cryptococcus neoformans, is a fungus of world-wide distribution occurring commonly as a saprophyte on the skin and mucous membrane of men and animals, and is unique in its ability to produce an abundant mucoid capsular material in tissue and culture. It is more frequently pathogenic than supposed, as evidenced by the increasing number of reports, approximately 300 cases having been recorded to date. The purpose of the presentation of these 21 cases from the Los Angeles County Hospital, diagnosed and treated during the period of 1945 to 1956, is to call attention to the disease, record its roentgen manifestations, stress the necessity for early diagnosis and discuss briefly the various methods of treatment.

The name Torula histolytica was first coined by Stoddard and Cutler[53] in 1916 because they believed the mucoid component of the lesions was due to the histolytic effect of the organism on the tissues. When this appearance was shown to be due to the abundant capsular material, many observers adopted the name Cryptococcus neoformans; however, both are in common usage.

The Torulae are usually thought to gain entry through the respiratory tract and thence spread to involve other parts of the body. Although various organs may be affected, the pulmonary, osseous, and central nervous systems are involved most frequently. Infection is not considered to be transmitted from man to man nor from animal to man.

The disease was first reported by Busse[11] in 1894 after recovering a yeast-like organism from a gummatous lesion of the tibia in a young woman. Buschke[10] in 1895 reported the same case. Since then there have been sporadic reports with various names assigned to the disease and organism. Stoddard and Cutler[53] in 1916 made an exhaustive study resulting in the first satisfactory description of the etiology and clinical features, and described the pathologic changes in detail. Additional comprehensive reports include those of Mosberg and Arnold in 1950,[45] who cited 172 cases from the literature, and Littman and Zimmerman[39] in 1956.

LABORATORY STUDIES

The fungus is readily demonstrated in tissue fluid, exudate, sputum, and biopsy material. It may be seen on direct examination of the smears or after preparation with the ordinary laboratory stains. The single most important examination is that of the cerebrospinal fluid, in which the organism can almost always be demonstrated with ease when the central nervous system is involved. In addition there may be an increase in the number of leukocytes, usually lymphocytes, but occasionally polymorphonuclears. When the disease presents as involvement of another system, the presence of normal spinal fluid may greatly affect the treatment and prognosis.

The organism is spherical to oval in shape, varying from 4 to 7 microns in diameter, and is surrounded by a refractile mucinous capsule easily demonstrated by preparations employing India ink. It is yeast-like, producing no endospores or mycelia and reproducing by budding. It grows readily on the common bacteriologic culture media and forms colonies which are visible within a few days. The colonies are

* Presented as an exhibit at the Fifty-seventh Annual Meeting of the American Roentgen Ray Society, Los Angeles, California September 25–28, 1956.

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usually tan to brown in color and have a glary, gelatinous appearance.

PATHOLOGY

One of the outstanding features of the disease is the tendency to form masses composed almost solely of organisms, frequently with little or no inflammatory response. The lesions as seen in the various organs are, for the most part, uniform. They are usually discrete, frequently solitary, but may be multiple. Their size varies widely from several millimeters of 10–15 centimeters. They are not surrounded by a fibrous capsule as is seen in granulomatous lesions due to tuberculosis; however, the demarcation from normal to abnormal tissue is abrupt. The consistency is usually gelatinous, being due to the overabundance of capsular material. The appearance of the lesion is frequently confused with that of neoplasm. On microscopic examination there are seen many organisms with dark staining nuclei and large capsules. There may be foci of necrosis scattered throughout the area.

In the exceptional instances where the lesions have been present for a long period of time, there is an infiltration of lymphocytes and giant cells producing firm, somewhat rubbery nodules in which the organisms may be difficult to demonstrate. Central necrosis may occur with the formation of cavities.

Regional lymphadenopathy, present in a small percentage of cases, is unlike that accompanying primary tuberculosis and coccidioidomycosis in that it tends to be a late manifestation of the disease.

CLINICAL FEATURES

There are no clinical features that are characteristic of torulosis and a diagnosis can be made only with recovery of the organism from the lesion. It must be kept in mind the organism is a normal saprophyte and care should be exercised in insuring that the organism, when found, is actually from the diseased part.

The patients appear to fall into two general groups: (1) those in whom symptoms are sudden in onset and the course rapid, with death ensuing in a few weeks; (2) those in whom the disease makes its appearance with a less dramatic onset and who may live for a considerable number of years. In the first group, meningitis is always present, whereas in the second, involvement of the central nervous system may occur late, or not at all. The disease most closely simulates tuberculosis, whether the involvement is of the lungs, meninges, or bone. Pulmonary lesions of considerable size may be entirely quiescent; being discovered only on routine survey roentgenograms. In other instances, there may be complaints of a nonspecific nature resembling either acute or chronic respiratory infection. The symptoms frequently include cough, productive sometimes of a mucoid sputum; hemoptysis; chest pains usually pleuritic in nature, and low-grade fever. Weight loss and a general deterioration in the nutritional status is seen occasionally.

Meningeal involvement produces the usual symptoms and signs of meningitis. A low-grade fever is frequently present. The findings may simulate brain tumor with increased intracranial pressure and neurologic signs referable to the area of involvement.

Osseous disease produces the clinical picture of osteomyelitis. There is usually a slightly warm, nontender swelling of the soft tissues over the involved bone. Eventually abscesses form which rupture with discharge of purulent or mucoid material. The systemic signs may be those of active infection, or may be entirely lacking.

REPORT OF CASES

Case 1. R.D., twenty-five year old white male, garage mechanic, had onset of symptoms in 1945 with dull aching pain and swelling in right gluteal region. He was admitted to the Los Angeles County Hospital six months later when the abscess ruptured. There were no systemic signs of disease.

Physical Examination: A warm, slightly tender swelling was present in the right gluteal

area from which there was a sinus tract discharging purulent material.

Course: Two weeks after admission the gluteal abscess was drained and the bone lesion thoroughly curetted. Torula histolytica was demonstrated in smear and culture. The abscess has remained healed. In 1947 the patient noted the onset of pulmonary symptoms consisting of orthopnea and dyspnea. These have progressed so that he now has severe limitation of his activities. He was treated from 1945 to 1949 with iodides. Tests for tuberculosis have always been negative.

Roentgen Examination (Fig. 1): (*A*) April 18, 1945, there was a destructive lesion in the right ischium. (*B*) May 12, 1945, there was rapid progression of the destruction, with slight periosteal reaction. Following curettement the area has remained healed. (*C*) August 1, 1946, there was diffuse infiltration throughout both

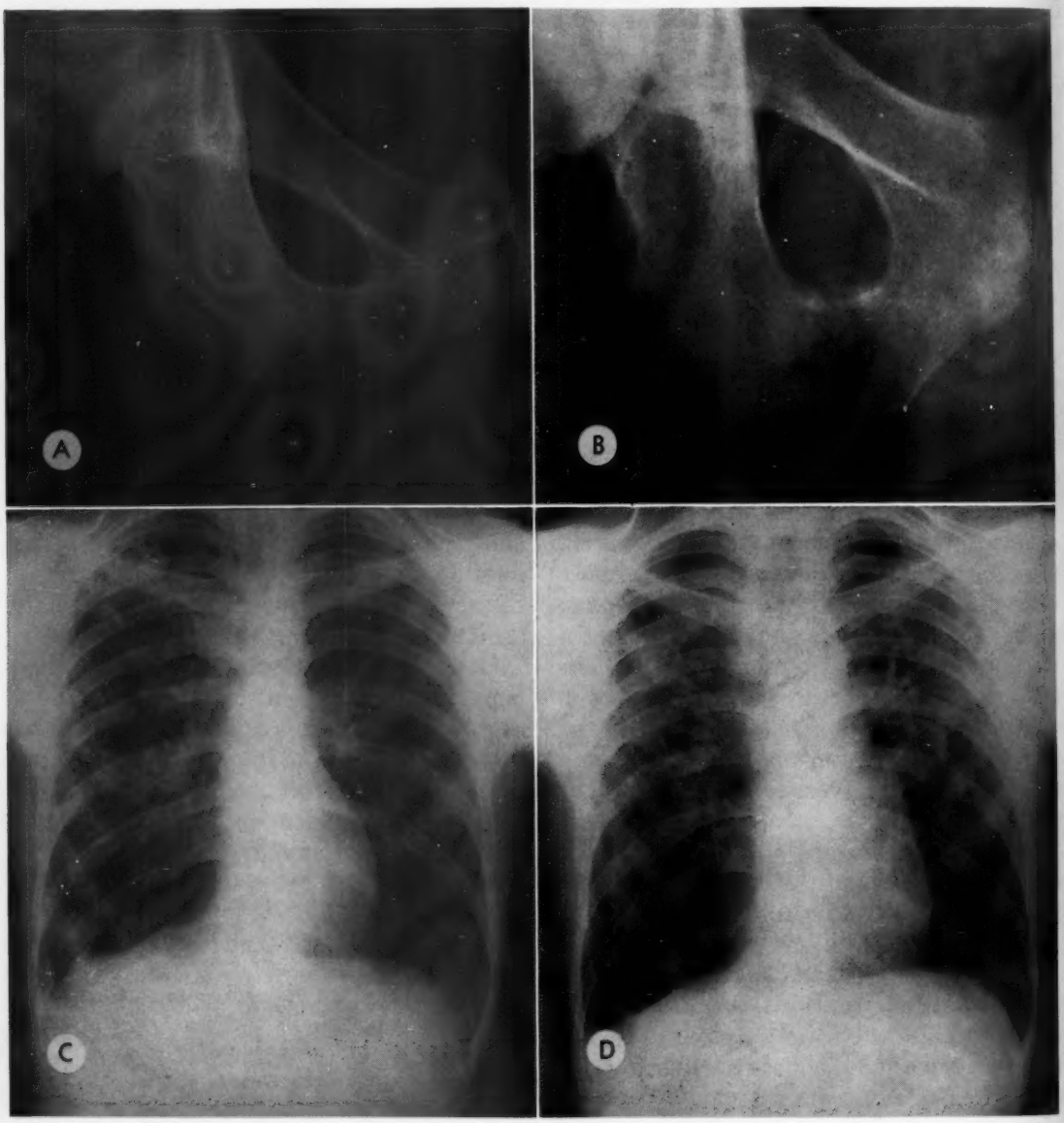

FIG. 1. Case 1. (*A*) April 18, 1945, destructive lesion in the right ischium. (*B*) May 12, 1945, rapid progression of the destruction; slight periosteal reaction now present. (*C*) August 1, 1946, diffuse infiltration throughout both lungs with slight pulmonary overexpansion. (*D*) March 17, 1955, slight regression of the infiltration, with gradually increasing pulmonary fibrosis and marked emphysema. Note the similarity to chronic fibrotic tuberculosis.

lungs with slight pulmonary overexpansion. (*D*) March 17, 1955, a slight regression of the infiltration has taken place but there has been gradual increasing pulmonary fibrosis with marked emphysema. Note the similarity to chronic fibrotic tuberculosis.

Case II. M.W., seventy-two year old Negro female, had onset of symptoms in 1949 consisting of chronic cough, hemoptysis, and right chest pain. She had had dyspnea on exertion for about one year.

Physical Examination: There were decreased breath sounds with a few scattered moist rales to auscultation and dullness to percussion over the right lung.

Course: The patient was admitted to the Los Angeles County Hospital in 1950 with the diagnosis of pulmonary tuberculosis. Acid fast bacilli were cultured from the sputum. Six months after admission a nontender, slightly warm swelling appeared over the anterior surface of the left tibia. An abscess was aspirated, and smear and culture of the material obtained revealed Torula histolytica. One year after admission the patient died of tuberculosis. On postmortem examination a large excavating lesion of the right lung was found with an abundance of tubercle bacilli. The Torula infection was entirely incidental.

Roentgen Examination (Fig. 2): There was a destructive cortical lesion in the diaphysis of the tibia.

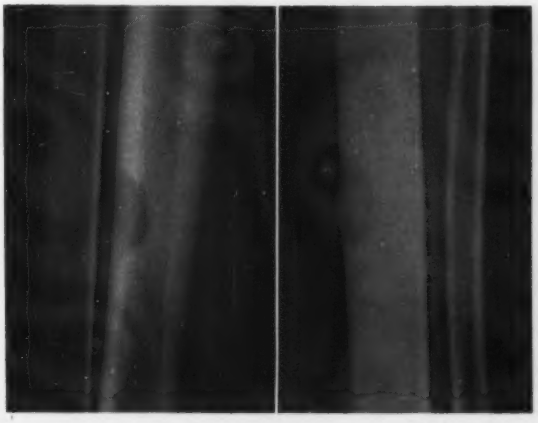

Fig. 2. Case II. Destructive cortical lesion in the diaphysis of the tibia.

Case III. S.A., fifty-two year old Negro female, had onset of symptoms in 1951 consisting of pain and stiffness of the right knee. She was admitted to Los Angeles County Hospital two months later as the pain became more severe.

Physical Examination: There was a swelling of the right lower thigh and knee, with local increase in heat, slight tenderness to palpation and moderate limitation of motion.

Course: Three weeks after admission the right knee was aspirated and 15 cc. of pus removed. Torula histolytica was seen on smear and culture of the aspirate. One month later, the knee was explored surgically and a very thick synovia was found with necrosis and fragmentation. The lesion of the patella was curetted as well as the synovia and cartilage. The patient was discharged from the hospital six weeks later. She has been seen over the intervening five years and remains well.

Roentgen Examination (Fig. 3): There was a destructive lesion of the upper pole of the patella with surrounding soft tissue abscess.

Case IV. M.W., thirty-one year old Negro female, never had symptoms referable to her chest but was seen at the Los Angeles County Hospital in 1948 for a duodenal ulcer. A routine chest roentgenogram revealed the pulmonary lesion.

Fig. 3. Case III. Destructive lesion of the upper pole of the patella with surrounding soft tissue abscess.

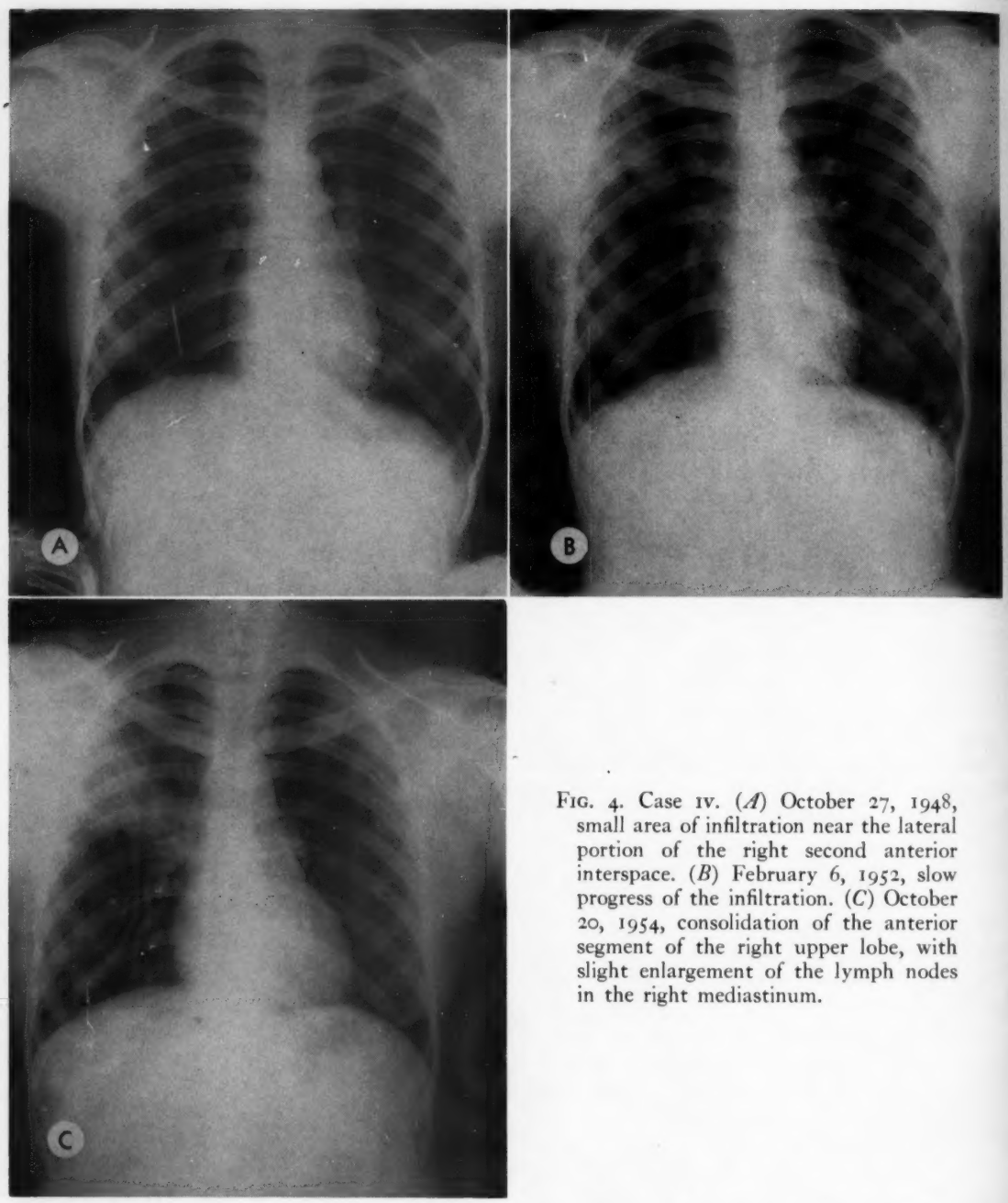

FIG. 4. Case IV. (*A*) October 27, 1948, small area of infiltration near the lateral portion of the right second anterior interspace. (*B*) February 6, 1952, slow progress of the infiltration. (*C*) October 20, 1954, consolidation of the anterior segment of the right upper lobe, with slight enlargement of the lymph nodes in the right mediastinum.

Physical Examination: Examination of the chest was entirely negative.

Course: The patient's P.P.D. #1 was positive. Numerous sputum and gastric secretion studies for tubercle bacilli were negative. The patient was treated with streptomycin and penicillin, but the lesion progressed over a period of six years and a segmental resection of the involved lung was done in 1954. The postoperative course was uneventful and she has remained well to date.

Pathology: The lung specimen was pale, grayish-brown in color and firm, and there was an infiltration extending from the hilus toward the periphery in a triangular fashion. The bronchi supplying the area were narrowed. The contiguous hilar lymph nodes were enlarged, and the gross appearance of the lesion was that

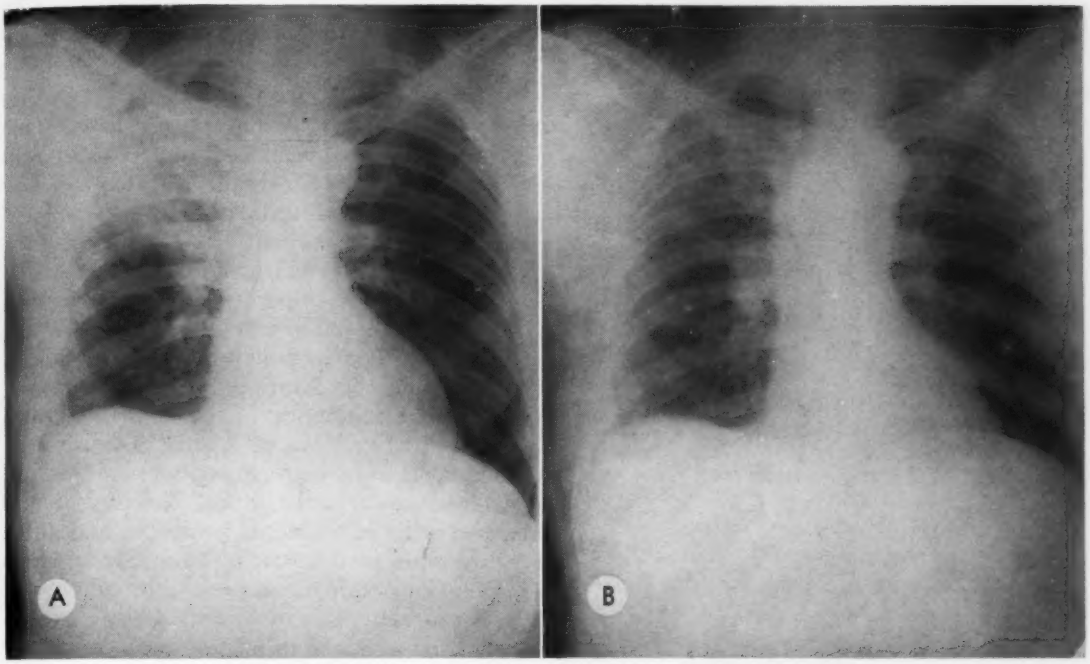

Fig. 5. Case v. (*A*) June 4, 1951, diffuse infiltration with slight enlargement of the lymph nodes in the right mediastinum. Laminagraphy revealed multiple small cavities in the right upper lobe. (*B*) February 29, 1952, partial clearing, without change in the size of the lymph nodes.

of a neoplasm. Torula histolytica was recovered from both the parenchymal and lymph node lesions.

Roentgen Examination (Fig. 4): (*A*) October 27, 1948, there was a small area of infiltration near the lateral portion of the right second anterior interspace. (*B*) February 6, 1952, the infiltration has progressed slowly. (*C*) October 20, 1954, the anterior segment of the right upper lobe has become consolidated. Slight enlargement of the lymph nodes in the right mediastinum is now present.

Case v. G.S., forty-eight year old white male, had onset of illness in 1947, characterized by cough productive of thick sputum and right anterior chest pain. He was seen by a private physician, who made a diagnosis of pulmonary tuberculosis. He was admitted to a sanitarium where a right phrenic crush and right pneumothorax were performed. Tuberculin tests and sputum analyses were negative. He was admitted to the Los Angeles County Hospital in 1951 complaining of pain in the right anterior chest and repeated episodes of hemoptysis.

Physical Examination: There were rales to auscultation and slight dullness to percussion over the upper one-half of the right lung.

Course: Bronchoscopic washings were obtained and revealed Torula histolytica on smear and culture. Ten months after admission, 1952, a right upper lobectomy was done. Postoperative course was uneventful and the patient has remained well.

Pathology: The specimen revealed dense infiltration in most of the right upper lobe and on cut section there were many irregular cavities varying in size up to 2 cm. Torula histolytica was seen in the sections.

Roentgen Examination (Fig. 5): (*A*) June 4, 1951, there was diffuse infiltration of the right upper lung, with slight but definite right mediastinal lymphadenopathy. Laminagraphy revealed multiple small cavities in the right upper lobe. (*B*) February 29, 1952, there was partial clearing, although the lymphadenopathy remained unchanged.

Case vi. F.W., thirty-five year old white female had onset of illness in 1949, marked by a cough productive of scanty mucoid sputum. The patient also complained of slight malaise.

Physical Examination: Scattered rales in the left lung were heard on auscultation.

Course: She was admitted to the Cedars of Lebanon Hospital in 1952 after a lesion was

FIG. 6. Case VI. Well delineated mass occupying the lingula of the left upper lobe.

discovered in the lingula of the left upper lobe. The patient was bronchoscoped and washings from this procedure revealed Torula histolytica. A segmental resection was performed. Six weeks after the operation and after discharge from the hospital the patient noted the onset of severe generalized headaches which were associated with anorexia and nausea and were followed shortly by symptoms of depression, irritability, and belligerency. A lumbar puncture was done and the specimen of spinal fluid contained Torula histolytica. She was then admitted to Los Angeles County Hospital and treated with large doses of mycostatin. Approximately six months later at another hospital the patient expired, four years after the onset of symptoms and one year following lobectomy.

Pathology: (a) Examination of the surgical specimen revealed a nonencapsulated, firm mass measuring about 10 cm. in diameter which on cut section was gray in color and had a gelatinous consistency. Torula histolytica was readily identified; (b) Postmortem examination showed a well advanced meningitis with thickening of the arachnoid, especially over the base of the brain. Torula histolytica was easily recovered.

Roentgen Examination (Fig. 6): There was a well delineated mass occupying the lingula of the left upper lobe of the lung.

CASE VII. E.B., forty-four year old Negro female, had onset of illness in 1950, characterized by marked weakness, diplopia and irrational behavior. She was admitted to Los Angeles County Hospital three weeks later.

Physical Examination: There was a bilateral third cranial nerve palsy and coarse tremors of both extremities. Superficial reflexes were absent and deep tendon reflexes were hypoactive.

Course: A lumbar puncture was done and the cerebrospinal fluid pressure was 175 mm. of water. On examination of the fluid there were numerous white blood cells, most of which were lymphocytes. Torula histolytica was identified on direct smear and culture. The patient was treated with sulfadiazine, penicillin, and autotransfusions of irradiated blood. She did not respond and expired five weeks after admission.

Postmortem Examination: There was a meningitis with the usual thickened arachnoid membrane over base of the brain, and a 3 cm. toruloma was found in the right lower lobe.

Roentgen Examination (Fig. 7): A well circumscribed 2 cm. nodule was demonstrated in the right lower lobe.

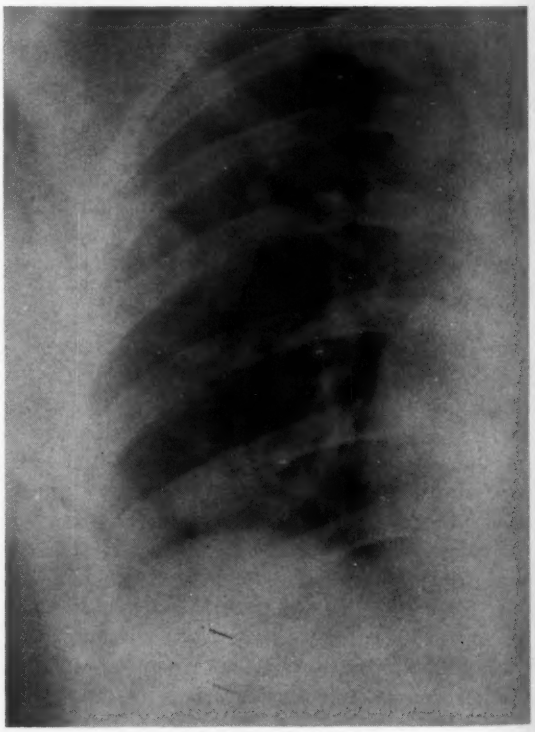

FIG. 7. Case VII. Well circumscribed 2 cm. nodule in the right lower lobe.

TABLE I

ANALYSIS OF 21 CASES OF TORULOSIS FROM LOS ANGELES COUNTY HOSPITAL, 1945 TO 1956

Case No.	Name	Age	Sex	Race	System	Roentgen Findings	Diagnosis	Course	Duration
I	R.D.	25	M	W	Osseous and pulmonary	Destruction of ischium, diffuse pulmonary infiltration (Fig. 1)	Biopsy and culture	Living, marked pulmonary insufficiency	12 yr.
II	M.W.	72	F	N	Osseous	Destruction of tibia (Fig. 2)	Biopsy and culture	Expired of pulmonary tuberculosis	2 yr.
III	S.A.	52	F	N	Osseous	Destruction of patella (Fig. 3)	Biopsy and culture	Living and well	5 yr.
IV	M.W.	31	F	N	Pulmonary	Infiltration of right upper lung (Fig. 4)	Resected specimen	Living and well	4 yr.
V	G.S.	48	M	W	Pulmonary	Infiltration with cavity in right upper lung (Fig. 5)	Bronchoscopic washings, resected specimen	Living and well	7 yr.
VI	Z.W.	35	F	W	Pulmonary	Mass of lingula of left upper lung (Fig. 6)	Bronchoscopic washings, resected specimen, cerebrospinal fluid culture, autopsy	Expired of meningitis	4 yr.
VII	E.B.	44	F	N	Central nervous system and pulmonary	Nodule of right lower lung (Fig. 7)	Cerebrospinal fluid culture and autopsy	Expired	2 mo.
VIII	A.B.	75	F	N	Central nervous system	None	Cerebrospinal fluid culture	Expired	1 yr.
IX	R.M.	49	M	W	Central nervous system	None	Cerebrospinal fluid culture and autopsy	Expired	10 mo.
X	E.F.	36	M	W	Central nervous system	None	Cerebrospinal fluid culture and autopsy	Expired	2 wk.
XI	F.P.	28	F	W	Central nervous system	None	Cerebrospinal fluid culture and autopsy	Expired	3 mo.
XII	L.L.	34	M	N	Central nervous system	None	Cerebrospinal fluid culture and autopsy	Expired	4 yr.
XIII	C.H.	32	F	N	Central nervous system	None	Cerebrospinal fluid culture	Expired	4 wk.
XIV	J.R.	45	M	W	Generalized	None	Cerebrospinal fluid culture, biopsy of supraclavicular lymph node	Living with disease	14 mo.
XV	H.B.	29	M	W	Generalized	None	Cerebrospinal fluid culture and autopsy	Expired	3 wk.
XVI	G.A.	47	M	W	Generalized	None	Cerebrospinal fluid culture	Expired	3 wk.
XVII	B.M.	24	M	W	Generalized	None	Cerebrospinal fluid culture and autopsy	Expired	2 wk.
XVIII	A.L.	26	F	W	Central nervous system and pulmonary	Infiltration of right upper lung, progressive	Cerebrospinal fluid culture and autopsy	Expired	15 yr.
XIX	W.S.	65	M	W	Central nervous system and pulmonary	Infiltrations of left upper lung	Cerebrospinal fluid culture and autopsy	Expired	1 yr.
XX	M.A.	35	F	W	Central nervous system and pulmonary	Mass of right upper lung	Cerebrospinal fluid culture	Living with disease	6 mo.
XXI	B.C.	46	M	W	Pulmonary	Infiltration of both upper lobes with cavities	Autopsy	Expired	2 yr.

DISCUSSION

The 21 cases (7 of which are described in detail above) comprising this report are summarized in Table I. The factors of sex, race, and age are tabulated and compared (Table II) with 100 cases gathered from the literature.[1–37,39–44,46–54,56–62] Our cases are almost equally divided between males and females, whereas in the reported cases there is a preponderance of males in the proportion of 3 to 1. In our series Caucasians are involved only twice as frequently as non-Caucasians, as compared with a reported ratio of 4 to 1. The age incidence coincides fairly well with that of previously reported cases, most of the patients being in the second, third, and fourth decades of life. We have observed no cases in the newborn as cited by Neuhauser and Tucker.[46]

The distribution by organs or systems of

TABLE II

COMPARISON OF CASES FROM LOS ANGELES COUNTY HOSPITAL WITH THOSE PREVIOUSLY REPORTED BY AGE, SEX AND RACE

	Los Angeles County Hospital	Survey
	21 Cases	100 Cases
Male	11	75
Female	10	25
Caucasian	14	80
Non-Caucasian	7	20
Age (second to fourth decades)	10	55

the 21 cases is shown in Table III. The central nervous system was involved in 15 of the cases. In 5 of these cases only the brain and meninges were affected; in 5, pulmonary lesions were also present; and in 5 the disease was generalized with involvement of the lungs, lymphatic system and skin. There were 6 cases with no involvement of the nervous sytem; in 3 cases only the lungs were affected; in 2, only the bones; and 1 case had combined pulmonary and osseous involvement.

The roentgen findings in the 9 cases with pulmonary lesions are presented in Table IV. These findings are nonspecific and may vary from a segmental, fine, lacelike infiltration limited to one or two interspaces (Case IV) to a dense consolidation (Case V). Lesions having the appearance of masses which may be mistaken for peripheral neoplasm, either primary or metastatic, are also encountered (Cases VI and VII). Cavitation, although apparently rare and reported only once in the survey of 100 cases from the literature, was observed in 2 of our patients (Cases V and XXI). Diffuse pulmonary infiltrations, although encountered in only 1 of our patients (Case I), are not uncommon.[4,33,40] It is notable that this patient, now under observation for twelve years, has developed cor pulmonale and has changes in his chest roentgenogram which could easily be mistaken for chronic fibrotic tuberculosis.

TABLE III

DISTRIBUTION BY ORGANS OR SYSTEMS

		Cases
Central nervous system		15
Central nervous system alone	5	
Central nervous system and pulmonary	5	
Generalized	5	
Pulmonary		3
Osseous		3
Osseous and pulmonary	1	

TABLE IV

CHARACTER OF PULMONARY LESIONS IN 9 CASES

		Cases
Discrete mass lesion		3
Segmental infiltration		5
Cavity	2	
Lymphadenopathy	2	
Diffuse infiltration (combined with osseous lesion)		1

The upper lobes were involved in 7 of the 9 cases of pulmonary torulosis. This is contrary to most of the other reports in which the lower lobes were more frequently involved.

While mediastinal lymphadenopathy has been described only once before,[4] it was present in 2 of our 9 cases of pulmonary torulosis. In Case V, the lymphadenopathy was present at the time the disease was discovered. In Case IV, however, the lymphadenopathy appeared after the patient was under observation for three years. The fact that lymphadenopathy in torulosis is fairly uncommon and may appear rather late is an aid in differentiating this disease from primary tuberulosis and coccidioidomycosis in which the lymphadenopathy tends to occur early and frequently.

The roentgen findings were the same in all 3 cases with osseous involvement, namely: a limited area of destruction with slight periosteal reaction (Cases I, II and III). The distribution of these bone lesions is apparently unpredictable, involving ischium, tibia and patella. The differential diagnosis of these lesions is extensive but primarily concerns tuberculosis, other fungus diseases, and neoplasm both primary and

secondary. There is a difference between the bone lesions of torulosis and those of coccidioidomycosis which is of considerable interest to us in Southern California in that the latter frequently involves bony prominences whereas the former would appear to have no such predilection.

In none of our cases were there observed abnormal intracranial calcifications as described in infants[46] despite the fact that 15 of the 21 cases had disease of the brain and meninges. Much has been written about torulosis being associated with neoplastic diseases, especially of the reticuloendothelial system.[14,61] Our failure to note any association with neoplastic conditions, and especially Hodgkin's disease, leads us to wonder if the infection in those cases was not a terminal event. We did note the association of tuberculosis and torulosis in 1 instance (Case II), in which the Torula infection was incidental and inconsequential. The association has also been reported previously.[41,57]

The prognosis is very grave. Although there have been reported spontaneous regressions of pulmonary lesions,[16] cures thus far, for the most part, have been limited to those cases in which there has been complete surgical removal. Death may occur from one month to fifteen years after onset, and is usually due to meningitis or brain abscess.

It is notable that 6 of our patients are living at the time of this report (Table 1). They have survived for periods of four months to twelve years, 3 with no evidence of disease, 2 with active involvement of the central nervous system, and 1 with extensive pulmonary disease. Of the 3 cases considered cured, 2 had pulmonary disease of the right upper lobe, and both had pulmonary resections. In 1 instance (Case IV) eight years have elapsed since the lesion was first seen and four years since operative intervention. In another (Case V) seven years have elapsed since the onset and five years since operation. The third patient (Case III) had infection of the patella and knee joint and is now well five years after the onset and four and one-half years following surgery. There are 3 other patients alive with disease: 1 (Case I) has combined osseous and diffuse pulmonary infection and it is now twelve years since the onset of the disease. The osseous lesion was resected and has remained healed; the pulmonary lesion has become stabilized. The other 2 are cases of Torula meningitis: 1, fourteen months (Case XIV) and the other six months (Case XX) after onset.

All of the common antibiotics, irradiated autotransfusions, intrathecal injections of irradiated human serum, killed typhoid bacilli, other forms of fever therapy, iodides and some of the newer antifungus drugs have been used without any appreciable effect.

SUMMARY

1. Torula histolytica (Cryptococcus neoformans) is a fungus of world-wide distribution. It is usually a saprophyte, but as a pathogen it is more frequent than commonly supposed, as indicated by the 21 cases which have been seen at the Los Angeles County Hospital between 1945 and 1956.

2. The epidemiology, mycology and pathology are reviewed briefly.

3. There are no characteristic clinical features of the disease and the diagnosis can be made only by recovery of the organism. The disease may be rapidly fatal or extend for periods of twelve to fifteen years.

4. In all, 9 patients had pulmonary lesions which were nonspecific in appearance, ranging from segmental infiltrations to discrete mass lesions indistinguishable from neoplasms, primary or metastatic. Both cavitation and mediastinal lymphadenopathy may be present.

5. There were 3 patients with osseous lesions consisting of a limited area of bone destruction with slight periosteal reaction.

6. Six of our patients are living; 3 without evidence of disease. Pulmonary resection was performed in 2 of these 3 patients, and a bone lesion was curetted in the third.

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THE CLINICAL SIGNIFICANCE OF THE TRACHEAL BRONCHUS*

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TRACHEOBRONCHIAL variations became clinically significant with the development of roentgenology, bronchoscopy, and, more recently, pulmonary surgery. The tracheal bronchus is one of the more interesting deviations, representing the extreme form of a series of variations seen only on the right side. Previously, tracheobronchial variations in general, and the tracheal bronchus in particular, had been anatomic curiosities. They have now assumed clinical significance to those engaged in the diagnosis and management of pulmonary pathology simply on the basis of their existence. A search of the literature failed to disclose any specific symptomatology or physical findings referable to the tracheal bronchus.

The stimulus for this study was a patient in whom bronchography and laminagraphy demonstrated a bronchus arising from the trachea and supplying the right upper lobe apical segment. This was as sharply delineated as in the pig or cow. Many of the cases reported previously are not so completely typical, but readily fit into the series of right-sided tracheal variants.

REPORT OF A CASE

The patient was a sixty year old white male who complained of a chronic, harsh, productive cough of two years' duration. Eighteen months prior to the time of admission, he had been seen in another hospital where the diagnosis of chronic bronchitis was made. It is interesting to note that at that time, except for mild inflammation of the tracheobronchial tree, nothing abnormal was noted at bronchoscopy. He gave no history of chest pain, hemoptysis, weight loss, dyspnea or orthopnea.

Physical examination at the time of the present admission revealed a well developed, well nourished, white male in no apparent distress. The physical findings, including those pertinent to the chest, were normal, as were the routine laboratory studies.

The routine posteroanterior and lateral chest roentgenograms were reported as being normal. On bronchoscopic examination, by Dr. Joseph P. Atkins, the orifice of an abnormal bronchus was noted arising from the right side of the trachea. No bronchus to the right upper lobe was seen arising from the right main stem bronchus. Bronchographic studies demonstrated the tracheal-apical bronchus (Fig. 1). In the erect position there was puddling of the contrast medium in that portion of the bronchus just distal to its origin from the trachea (Fig. 2).

Laminagraphy (Fig. 3), without contrast medium, revealed the anomalous bronchus. A careful study of the roentgenograms made on admission did not disclose any shadow suggesting a tracheal bronchus.

REVIEW OF LITERATURE

The fact that this anomaly occurs and can be readily diagnosed is of importance to those dealing with pulmonary lesions. Although the tracheal bronchus is usually an incidental finding, patients occasionlly have nonspecific symptoms due to pathologic conditions involving the abnormal bronchus. Epstein[5] reported the case of a patient with a history of cough productive of copious quantities of yellowish sputum that was occasionally blood streaked. Routine roentgenograms demonstrated a large density in the right upper lobe. The bronchoscopist reported an abnormal bronchus arising from the trachea on the right side. At operation, an adenoma was discovered in the supernumerary apical bronchus.

Ferguson and Neuhauser[6] described a

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Fig. 1. Bronchogram of right upper lobe demonstrating the apical segmental bronchus arising from the trachea above the carina.

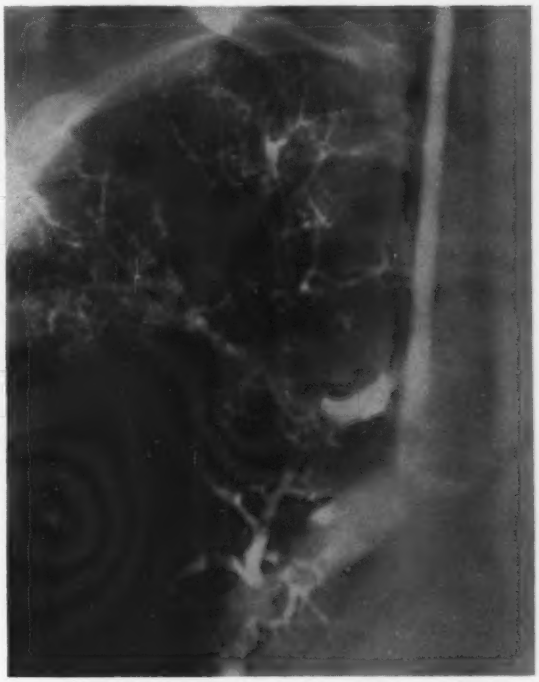

Fig. 2. In the erect position, contrast medium is seen puddling in the proximal portion of the abnormally situated right apical bronchus.

patient with frequent, repeated episodes of "pneumonia" in the right upper lobe. Investigation demonstrated an apical bronchus arising from the trachea above the bifurcation. In addition, there was narrowing of the trachea from the point of origin of the abnormal bronchus to the carina. They recommend that any patient in whom localized areas of atelectasis or emphysema are found be subjected to bronchoscopic study.

Monk[15] described the autopsy findings of a 27 year old female who died of a cerebral hemorrhage. There was a displaced bronchus to the apical and subapical segments of the right upper lobe. Furthermore, the right pulmonary artery divided into three main branches, one to the lower and middle lobes, one to the anterior and posterior segments of the upper lobe, and the third to those segments of the upper lobe supplied by the displaced apical bronchus. The pulmonary venous system was normal.

Brea *et al.*[1] reported a case in which an aberrant bronchus was found leading to an infected diverticulum in the region of the right upper lobe. The bronchus arose 2 cm.

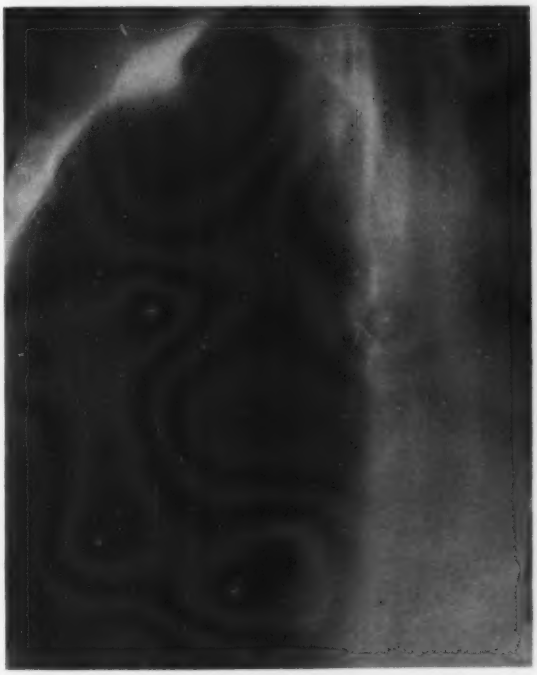

Fig. 3. Laminagram clearly demonstrating the relationship of the right apical segmental bronchus to the carina and azygos vein.

above the carina on the right side. This patient had fever and complained of cough and pain in the right hemithorax.

Other cases have been reported by Kato,[14] Zaffran,[19] Raton,[16] and Hulse and Curtis.[11] Gerson and Rothstein[9] and Kato[14] have reported cases in which there was an accessory (supernumerary) bronchus supplying the right upper lobe.

THEORIES OF PULMONARY EVOLUTION

If any anomaly can be related to a general plan, whether developmental or empiric, roentgen diagnosis is simplified. About 1900, when the theory of evolution was forty years old, there was much speculation about the evolution of the bronchial tree. Three main theories arose. The first of these was the Reduction theory, whose chief proponents were Aeby (1878, 1880, and 1882), D'Hardviller (1896, 1897) and Bremer (1904). This theory postulated a basic ground-plan for the mammalian bronchial tree encompassing all the components of the extant mammalian bronchial distribution including bilateral symmetry and bilateral eparterial bronchi. From this primitive pattern, the Reductionists felt that all variations, as found in the majority of the mammals, were the result of reduction and finally suppression of a portion, or portions, of the original distribution. The European porcupine, (*Hystrix cristata*), which has a bilateral hyparterial bronchial tree, is the most extensive example of this.

Subsequently, two similar theories were advanced, which by different reasoning arrived at conclusions opposed to the Reduction theory. The Extension theory and the Migration theory consider the bilaterally symmetric hyparterial bronchial plan as the rudimentary plan of the modern mammalian lung.

The Migration theory, (Narath, 1892), assumes a primitive mammalian bronchial distribution which is bilaterally symmetric with a fixed number of derivative branches. The subsidiary outgrowths have the potential of moving or "migrating" from their initial locus to new points of origin on the stem bronchus. In this manner the type of bronchial tree is altered.

The bronchus which is to eventually supply the upper lobe of the fully developed right lung is, according to Narath, first found as a side branch of the hyparterial bronchus, or first ventral derivative of the right main stem bronchus. It then "migrates" from this primitive site dorsally onto the stem bronchus as the apical bronchus supplying the apical segment of that lung. It has the capacity of continuing to "wander" further cephalad along the stem bronchus. When it reaches a point above the intersection of the pulmonary artery and the right stem bronchus, it becomes eparterial. It may "migrate" as far as the carina or to the right side of the trachea as in the cloven-hoofed animals.

The Selection theory proposed by Huntington[12] in 1920, postulates that any portion of the respiratory system lined with entoderm has the inherent capacity of inaugurating bronchial buds from its surface. The amount of intracoelomic space available for pulmonary extension regulates the location of the total peripheral respiratory area. This in turn governs the selection of the points of epithelial budding.

The Selection theory does not imply wandering or "migration" on the part of the abnormally situated bronchus, but states that the aberrant bronchus has simply arisen at the site of its location according to the demands of the peripheral lung distribution.

Huntington further points out that the right stem bronchus and the right side of the trachea should be the sites of preference for the abnormally situated bronchus on the basis of the anatomy of adjacent structures. The right vagus nerve is dorsally placed with respect to the trachea while the right pulmonary artery traverses anterior to it. This leaves a space through which the right eparterial bronchus projects.

EMBRYOLOGY

The original laryngo-tracheal outgrowth appears about the fourth week of embryo

life and at that time is a bluntly rounded outpouching from the floor of the pharynx. The direction of growth is caudad, and by the sixth week there appears, at the distal enlarged end of the trachea, the beginning of the bifurcation marking what are called the lung buds. The trachea bifurcates giving rise to the right and left stem bronchi. The lobar branches of the stem bronchi arise from their ventral and dorsal aspects. This is not a dichotomous process as formerly believed, but is monopodial with the stem bronchi continuing to grow beyond the point of branching without change of direction.

Gruenfield and Gray[10] describe the abnormally situated apical bronchus as being an "atavistic anomaly." In the strict genetic sense of the word this is not true inasmuch as there is no evidence indicating that, in man, the condition is inherited. In the phylogenetic interpretation, it may be a correct assumption only in the broadest sense, if one is of the opinion that man has evolved from certain of the domestic animals. Schwable[17] promulgated that this condition represents a "developmental error of endogenous origin; that is, it is the result of an inherently faulty germ plasm." This statement certainly does not hold for the pig nor the cow and does not seem to apply in the reported cases in man.

DISCUSSION

A study of comparative anatomy[4,18] reveals that the bronchus supplying the right upper lobe normally arises from the trachea in swine, cattle, sheep, goats, camels, and giraffes.[3] It should not be surprising, therefore, to find this same situation existing in any particular individual as an anatomic variation which exists, not as the result of an inherited trait, but simply as the result of a departure from the normal human bronchial pattern to that usually present in the aforementioned lower forms.

To the best of our knowledge, there have been no cases reported of an abnormal bronchus arising from above the bifurcation of the trachea to the left upper lobe in

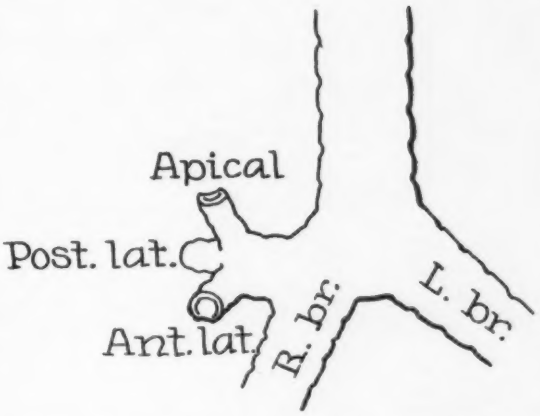

Fig. 4. Sketch of normal bronchial distribution to right upper lobe. (After Jackson and Huber.[13])

individuals surviving beyond the embryonal stage. Bremer[2] in 1932, reported on a series of 80 embryos from the Harvard Medical School Collection of which 4 demonstrated abnormal bronchial buds from the right side of the trachea. One of the younger embryos had two buds arising from the right side while another had one from the right as well as from the left. Bremer speculates that the relatively high incidence in embryos as compared to that found in adults indicates "resorption" of the abnormal bronchial bud in the majority of instances. Of those that persist into adult life, he postulates that they give rise

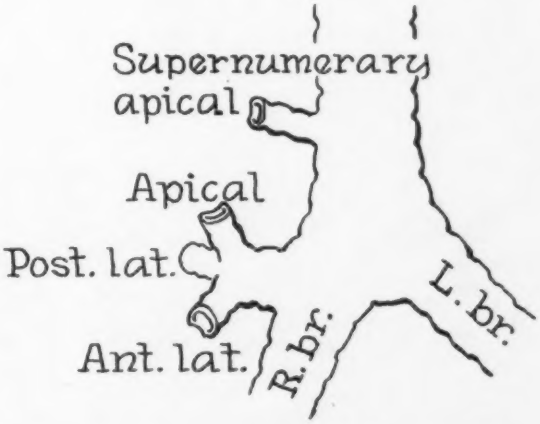

Fig. 5. Sketch of supernumerary right upper lobe bronchus. In addition to the normal segmental bronchial pattern, a supernumerary bronchus also supplying the right upper lobe arises from the trachea.

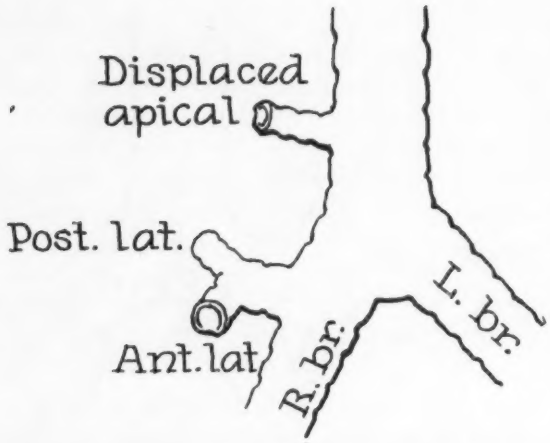

Fig. 6. Sketch of displaced right upper lobe bronchus. The bronchus to the right apical segment arises from the trachea. The bronchus to the right upper lobe has only two divisions, the postero-lateral and antero-lateral segmental bronchi.

to tracheal diverticula, cysts, rudimentary mediastinal lobes or form part of the right upper lobe. Another possible fate is an outpouching of the tracheal wall at the "weak spot" of incomplete or partial resorption of the abnormal bud. This may occur during shouting or the Valsalva maneuver resulting in the formation of a tracheocele.

Although we feel that the frequency of this finding will increase with the number of bronchoscopic and bronchographic examinations performed, it is possible that the anomalies of the tracheobronchial tree described by Bremer were merely one of multiple anomalies that contributed to

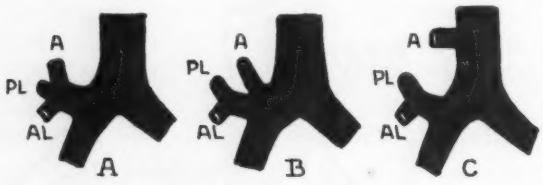

Fig. 7. Sketch of various sites of origin of the apical bronchus of the right upper lobe: AL—antero-lateral segmental bronchus; PL—postero-lateral segmental bronchus; A—apical segmental bronchus. (*A*) Normal bronchial distribution to the right upper lobe. (*B*) Simple "splitting off" of the apical bronchus. (*C*) Apical segmental bronchus arising from the trachea. (After Foster-Carter.[8])

the expulsion of the embryo from the uterus. If so, the figure of 5 per cent would not represent the true incidence even in embryos.

The abnormal bronchus may arise anywhere along the right main stem bronchus to as high as 5 cm. above the carina.[9] The majority were located 2 cm. or less above the bifurcation, the closest to the carina being 0.2 cm. The smallest and largest diameters were 0.5 cm. and 1.0 cm. respectively with the average being 0.7 cm. The longest abnormal bronchus was 2.0 cm. and the shortest 0.6 cm. with the average being 0.9 cm. In the case being presented the bronchus arose 3.8 cm. from the carina, was 3.0 cm. long and approximately 0.6 cm. in diameter as measured on routine laminagrams.

Foster-Carter[7] distinguishes between "supernumerary" (Fig. 5) and "displaced" (Fig. 6) bronchi. The former, which are comparatively rare, are defined as a bronchus arising from the trachea in addition to those normally present to the right upper lobe and not simply one of the normally present bronchi abnormally placed. This latter situation is referred to as a "displaced bronchus" and is the more common finding. Displacement of the apical bronchus can range from simple splitting of the eparterial bronchus to complete splitting, to upward displacement of the trachea. The degrees of displacement are demonstrated in Figure 7 as taken from Foster-Carter.[8] When a displaced apical bronchus is present, it can always be distinguished from a supernumerary bronchus by the fact that the eparterial bronchus has only two divisions, the anterior and the posterior instead of the normal three.

Foster-Carter,[8] in 1942 confirmed what Bremer[2] had suspected earlier, when he demonstrated that very rarely the supernumerary bronchus may give rise to a separate supernumerary apical lobe, separated from the remainder of the upper lobe by a fissure, and different altogether from an azygos lobe.

Because the various sites of orgin of the

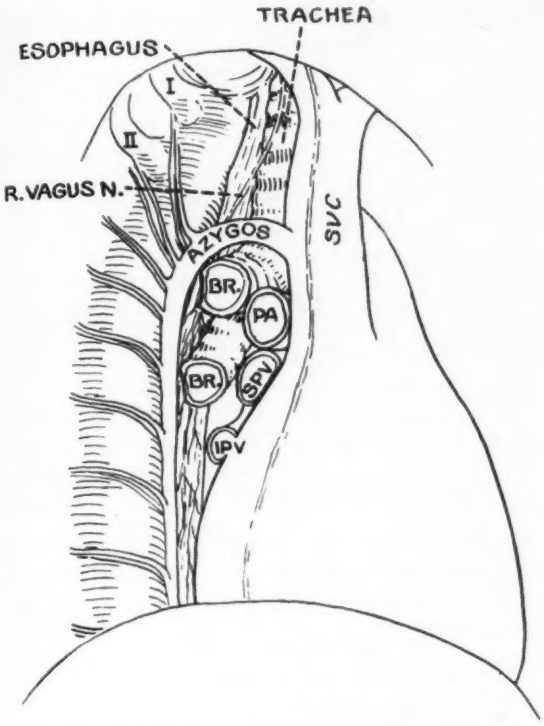

FIG. 8. Sketch of structures of the right side of the mediastinum. The arterioneural space referred to by Huntington[12] is demonstrated. However, this sketch illustrates that from the thoracic inlet to the origin of the right lobar bronchus, the trachea is intimately related to the parietal and visceral pleura except for the interpositioning of the vagus nerve and the azygos vein.

aberrant bronchus, terms designating their location with respect to the tracheobronchial tree seem to be indicated. The relationship of the displaced or supernumerary bronchus to the carina lends itself quite readily to the following terminology; carinal being those arising at the bifurcation or 1 cm. above it and tracheal being those arising from the trachea proximal to 1 cm. above the carina.

The "arterio-neural space" described by Huntington[12] extends from the level of the pulmonary artery to the thoracic inlet on the right side. Everywhere along this distance, the trachea and right stem bronchus are intimately associated with the parietal, and therefore, the visceral pleura of the right lung. Exceptions are the sites of the vagus nerve and azygos vein. It is, therefore, not inconceivable that the aberrant bronchus could arise from the right side of the trachea as far proximally as the thoracic inlet. The highest tracheal bronchus reported arose 5 cm. above the carina.[9]

A comparison of the structures of the right and left sides of the mediastinum clearly elucidates the absence of tracheal bronchi arising from the left (Fig. 8 and 9). The pulmonary artery, ligamentum arteriosum, aortic arch and its branches, and the recurrent laryngeal nerve obliterate what on the right is the "arterio-neural space."

SUMMARY

The case history of a patient in whom the bronchus to the right apical segment arose from the trachea is presented. Once identified, the tracheal bronchus has no particular clinical significance. The pathologic

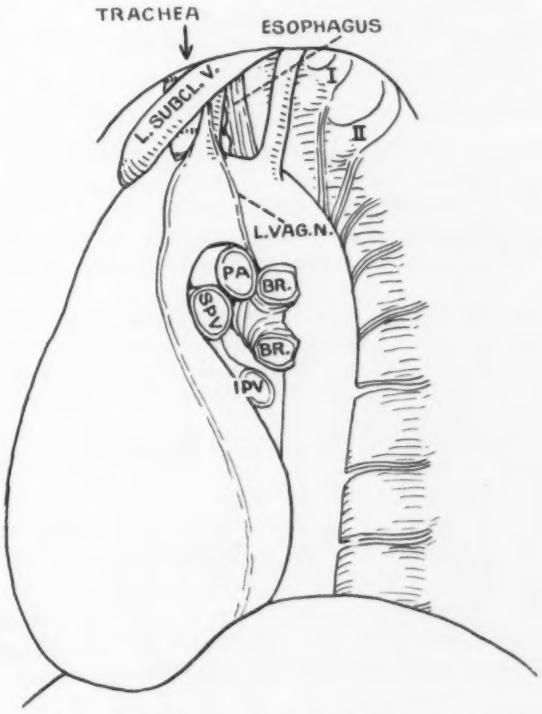

FIG. 9. Sketch of structures of the left side of the mediastinum. The left upper lobe is separated from the trachea by the left subclavian vein, the pulmonary artery, the aortic arch and its branches, the left vagus and the left recurrent laryngeal nerves.

findings associated with the anomaly are characteristic of those associated with any segmental bronchus.

A correlation has been drawn between the Migration and Selection theories of pulmonary evolution. It is suggested that the latter simply amplifies the former and that the theories are not dissonant.

The terms tracheal and carinal are suggested to designate the abnormal site of origin of the bronchus. These suggestions are not intended to conflict with Boyden's[3] term of preeparterial bronchus, but rather supplement it by adding terms of clinical topographic significance.

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Dr. Joseph P. Atkins, Professor of Broncho-esophagoscopy, granted permission to report the case history. We acknowledge gratefully the suggestions and guidance of Dr. O. V. Batson, Professor of Anatomy, Graduate School of Medicine of the University of Pennsylvania.

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VOL. 79, NO. 2

ROENTGENOGRAPHIC FEATURES OF NEURENTERIC CYSTS*

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IT HAS long been recognized that abnormalities in mesodermal development may occur in association with congenital anomalies of the spinal cord and meninges. Less commonly, entodermal tissues may also be involved, in which case a neurenteric cyst may result. By neurenteric cyst we refer to a cystic structure having a wall histologically resembling some segment or segments of the foregut. This cyst may have connections by means of a stalk to the meninges and spinal cord through a tunnel-like defect in the vertebral bodies.

Three patients having this unusual anomaly have been seen at this hospital in the past five years. Information on a fourth has been obtained through the courtesy of the Children's Hospital, Houston, Texas, and Dr. Bernard Rosen of Corsicana, Texas. The roentgenographic abnormalities seen in each patient have shown a remarkable similarity and their recognition should suggest the diagnosis.

REPORT OF CASES

CASE I. P.M. A379247. This patient has been reported previously by Holcomb and Matson.[5] He was four and one-half years old when he was admitted in 1951, with a history of repeated respiratory tract infections. Roentgenograms (Fig. 1) showed multiple anomalies of the vertebral column in the lower cervical and upper dorsal area. In the upper dorsal region the vertebral bodies were widened, as was the neural canal, and there was an oval defect in the vertebral bodies about D3. There was, in addition, a soft tissue mass in the mediastinum just to the right of the midline at the level of the defect in the vertebral bodies. This mass displaced the esophagus anteriorly and to the left. Myelography failed to show any connection between the subarachnoid space and the mass. The preoperative diagnosis was anterior meningocele. Laminectomy was performed and a solid cord, 5 to 6 mm. in diameter, was found, merging intimately with the middle of the anterior surface of the spinal cord and passing forward through the defect in the vertebral bodies. Thoracotomy was carried out and the mediastinal cyst was resected except for its posterior attachment to the vertebrae in the region of the defect. Microscopically, the cyst wall resembled esophagus.

CASE II. F.G. A415307. This nine day old, white, male infant was admitted in 1954, referred from another hospital for repair of a diaphragmatic hernia. Roentgenograms (Fig. 2) showed the right diaphragmatic hernia, but there were also congenital malformations of the upper dorsal spine with spina bifida, widening of the neural canal and a large defect in the upper dorsal vertebral bodies. These findings suggested the possibility of a neurenteric cyst.

The hernia was repaired and a duplication of the jejunum, which extended up with the hernia to the right side of the mediastinum, was excised. Postoperative barium swallow study showed a soft tissue mass overlying the defect in the vertebrae with anterior displacement of the esophagus.

Two months later the patient was re-admitted because of persistent cough and failure to thrive. A repeat barium swallow examination again showed the posterior mediastinal mass (Fig. 3). Myelography was attempted but was unsuccessful. An exploration of the upper dorsal spinal canal showed a normal appearing cord with a widened canal. At thoracotomy the mass was found to be firmly attached to the anterior surface of the vertebral bodies by a thick fibrous band and was also densely adherent to the esophagus. The cyst was excised and microscopically its wall resembled small intestine.

The patient died on the fourth postoperative day, and at postmortem examination the band of tissue which had been connected with the cyst passed through the defect in the vertebral

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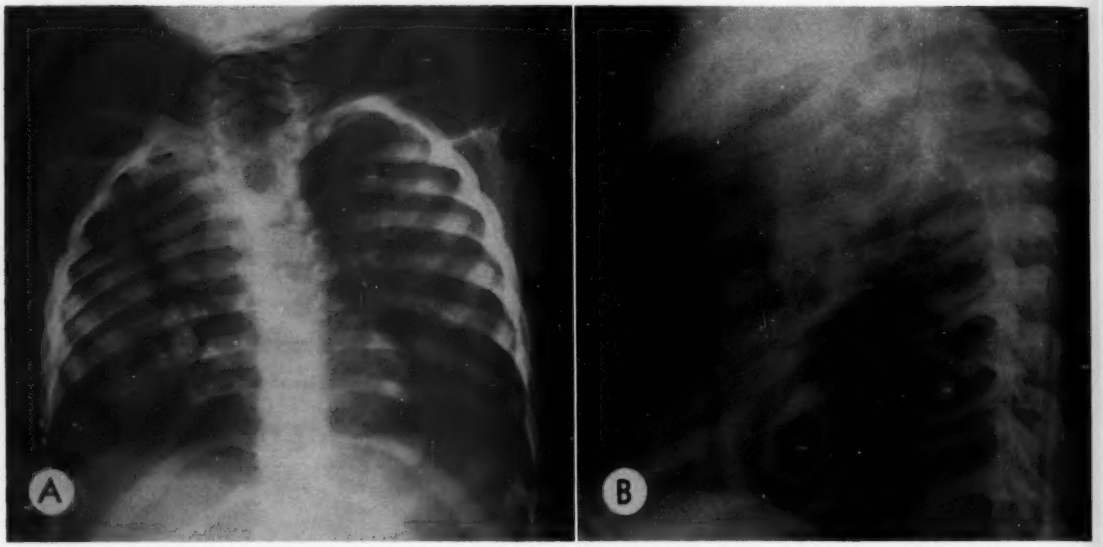

FIG. 1. Case I. P.M. (*A* and *B*) There is a soft tissue mass in the posterior mediastinum pushing the trachea anteriorly. Numerous congenital anomalies are present involving the lower cervical and upper dorsal vertebrae and there is a circular defect involving the bodies of D_3–D_4.

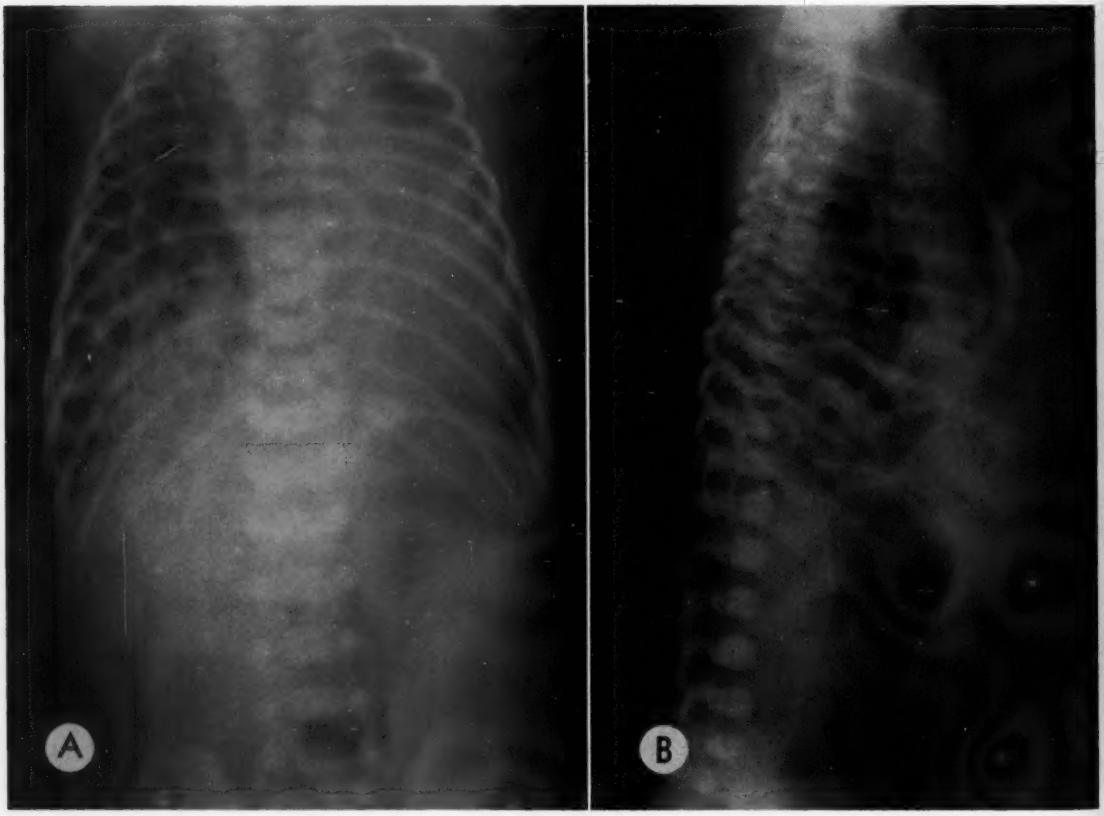

FIG. 2. Case II. F.G. (*A* and *B*) Note the extensive anterior spina bifida of the upper dorsal vertebral bodies with widening of the neural canal. The loops of intestine in the right hemithorax obscure the soft tissue posterior mediastinal mass.

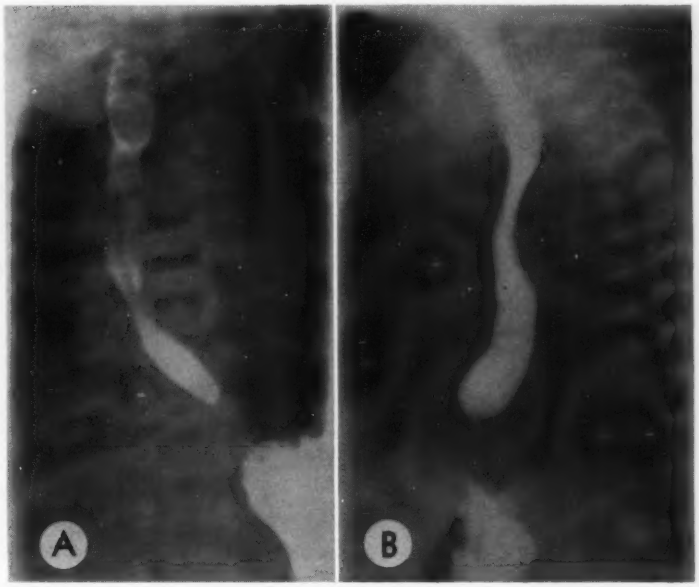

Fig. 3. Case II. F.G. (*A* and *B*) The neurenteric cyst in the posterior mediastinum causes slight compression and anterior displacement of the esophagus. The hernia has been repaired.

bodies and ran cephalad to merge with the cervical cord. The stalk contained elements of neural tissue as well as smooth muscle.

Case III. This newborn male infant was admitted to the Children's Hospital, Houston, Texas, in acute respiratory distress and with a flaccid paralysis of the lower extremities. Roentgenograms (Fig. 4) showed a large soft-tissue mass in the right hemithorax associated with congenital anomalies of the upper dorsal spine including a defect in the vertebral bodies.

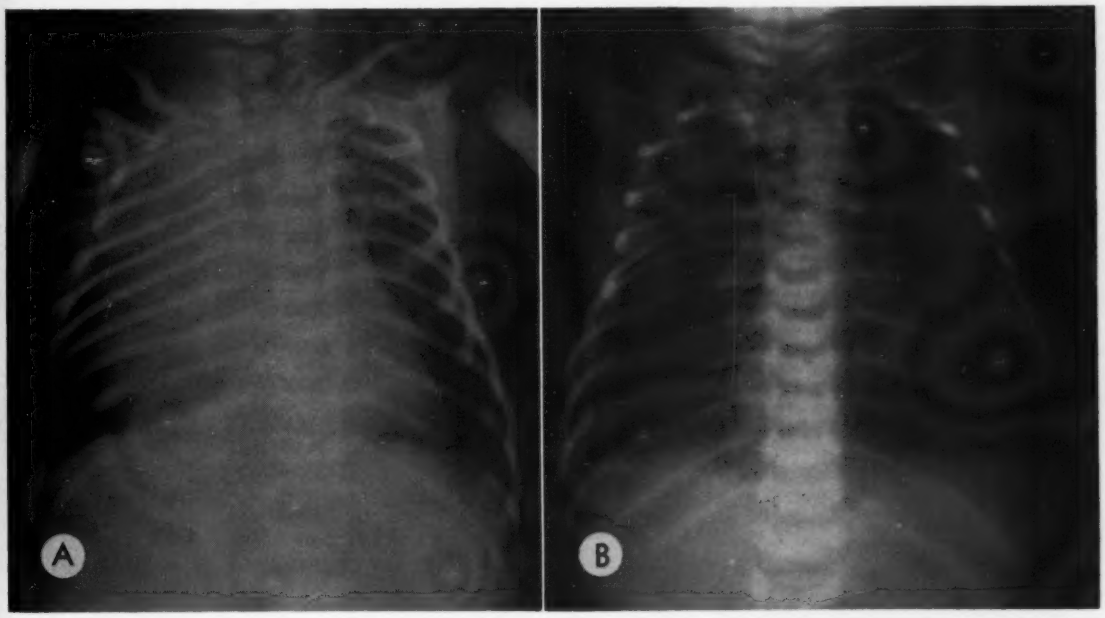

Fig. 4. Case III. (*A*) Preoperative. (*B*) Postoperative. *A* shows the large mediastinal enteric cyst extending into the right hemithorax. The defect in the bodies of D_3 and D_4 and the widening of the neural canal show more clearly on *B*, a postoperative examination.

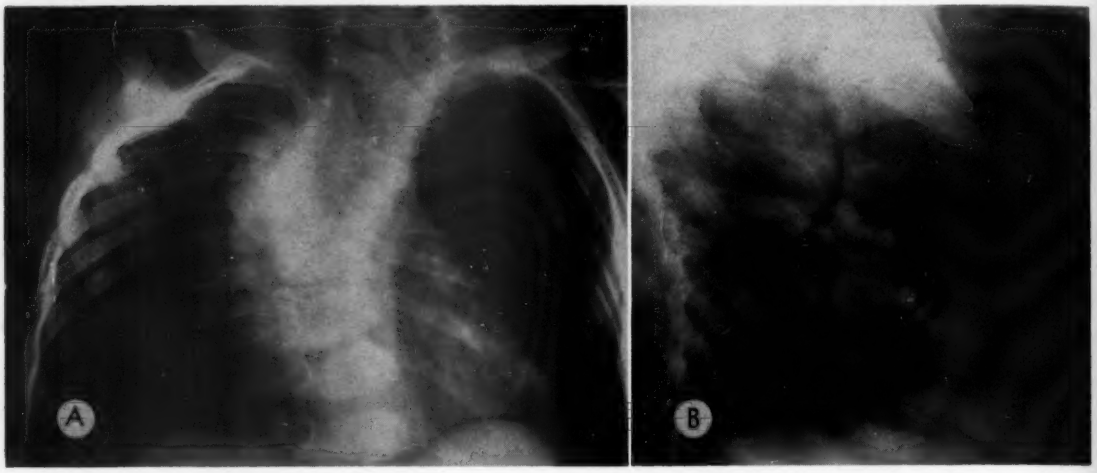

FIG. 5. Case IV. P.G. (*A* and *B*) Numerous anomalies of the lower cervical and the dorsal spine are evident. Note the widening of the neural canal in the upper dorsal area and the extensive anterior spina bifida. The soft tissue mass can be seen displacing the trachea anteriorly and extending to the right of the spine.

At thoracotomy the mass was found to lie in the mediastinum and had a stalk attached to the vertebrae in the region of the defect. During removal of the mass this attachment was divided and resulted in a leak of cerebrospinal fluid which was controlled by sutures. Postoperatively, the infant regained normal movements of the extremities. The thoracic mass provided to be a cyst having a wall with features of stomach as well as esophagus.

CASE IV. P.G. A438479. This four year, ten months old white boy was admitted to the Children's Medical Center in 1955 because of scoliosis and left-sided weakness. Physical examination revealed features of an upper motor neuron paralysis on the left side and a right Horner's syndrome.

Roentgenograms (Fig. 5) disclosed numerous congenital anomalies of the lower cervical and upper dorsal spine with failure of segmentation, widening of the neural canal and a large midline defect extending through the bodies of several upper dorsal vertebrae. A soft tissue mediastinal mass overlay the region of this defect and caused anterior displacement and compression of the trachea as well as the esophagus. A diagnosis of neurenteric cyst was suggested.

Myelography failed to demonstrate any direct communication between the mediastinal mass and the subarachnoid space but a space-occupying lesion was demonstrated in the upper dorsal region anteriorly. At laminectomy this proved to be a cystic structure adherent to the cord, and at its cephalic end a small amount of the cyst wall was imbedded in the cord itself. Sixteen cubic centimeters of chocolate colored fluid were aspirated from the cyst which was then divided and invaginated through the defect in the vertebral bodies. One cubic centimeter of pantopaque was introduced through the defect into the mediastinal mass which was then outlined on postoperative roentgenograms (Fig. 6). Three weeks later at thoracotomy the neck of the cyst was found to pass into the bony defect. The mass was excised and microscopically its wall resembled esophagus.

DISCUSSION

Several hypotheses have been presented in an attempt to explain the development of this anomaly. Bremer[2] has suggested that a neurenteric cyst may result from the partial obliteration of an accessory neurenteric canal. In the human embryo at an early stage of development a canal, the neurenteric or chorda canal, develops in relation to the formation of the notochord. It passes from the yolk sac, which is destined to form the intestinal tract, through the primitive knot to the amniotic cavity. Hence, there is a communication from the gut to the dorsal surface of the embryo passing through the midline dorsal structures. This is a normal but very short lasting connection and its final location in the

fully developed human is at the tip of the coccyx. Bremer suggests that any connection between the intestinal tract and the midline dorsal structures above the coccyx is due to the previous existence of an accessory neurenteric canal.

It is extremely rare for an accessory canal to remain patent. Usually it disappears completely but obliteration of the canal may be only partial with other segments remaining either as cysts or fibrous cords. Connections with the intestinal tract or dorsal surface of the skin may, or may not, disappear.

Bremer has also pointed out that the former presence of such an accessory canal may be recognized in several ways. For example, two complete vertebral bodies may form, one on each side of the canal. Later, when the canal involutes and disappears, the bodies may come together and their median pedicles fuse to form a bony, cartilaginous or fibrous spur which projects between the divided spinal cord. This results in the condition we know as diastematomyelia. Another possibility is that the vertebral bodies may develop around the canal and then the canal may involute to a fibrous cord except for one area which remains patent, resulting in the anomaly referred to as a neurenteric cyst, *i.e.*, a cystic structure of intestinal origin having a connection with the meninges and spinal cord through a defect in the vertebral bodies. It is possible that the giant diverticulum occasionally reported[4] as passing from the jejunum through a defect in the right crus of the diaphragm to the posterior mediastinum may represent the unobliterated proximal portion of an accessory canal.

Two patients with this anomaly have been presented by Fallon, *et al.*[3] who offer another, and probably less satisfactory, explanation of the embryogenesis. They point out that the notochord, at an early stage of its development, forms part of the primary entodermal cavity. Normally this notochordal plate becomes completely separated from the entoderm and later becomes surrounded by mesoderm which develops into the spinal column. They postulate that if the notochord drew some of the entodermal lining with it, then abnormalities in the formation of the vertebrae might well occur since the mesoderm would be unable to completely surround the notochord, and duplications and cysts could develop from the entodermal diverticulum. They suggest that the anomalies in the posterior arches of the vertebrae occur as a result of an associated disturbance of the sequence of the development of the vertebral bodies. This fails to explain, however, the midline dorsal cutaneous and subcutaneous abnormalities which may occur, for example, with diastematomyelia, nor would it necessarily account for the gross anomalies reported by Bell,[1] one of which, that of Morel-Gross, had a large open communication between the midline of the back and the greater curvature of the stomach passing between the divided vertebral column.

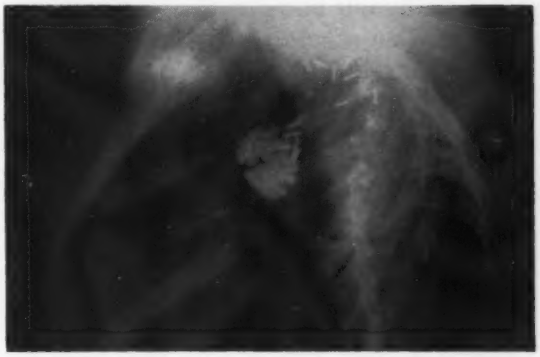

Fig. 6. Case IV. P.G. Lateral roentgenogram of the upper thorax shows the cyst filled with pantopaque which had been injected through the defect in the vertebral bodies at the time of laminectomy. The metallic clips lying anterior to the spine are attached to the wall of the intraspinal cyst which was invaginated through the vertebral defect into the mediastinum.

McLetchie and co-workers[6] suggest that neurenteric cysts as well as diastematomyelia and Klippel-Feil anomaly "arise as the result of localized duplications of the notochord, or faulty localized notochordal differentiation, either of which may or may not be attended by the formation of entoectodermal adhesions with the formation of neural or alimentary anomalies."

Clinically our patients had no characteristic signs or symptoms, but the combination of a mediastinal mass associated with cleft vertebrae and widening of the neural canal was evident on the roentgenograms in each case. Case II demonstrates the abnormality particularly well. A jejunal diverticulum extended up to the right side of the mediastinum and a mediastinal cyst with a wall resembling small intestine was connected by means of a stalk containing smooth muscle and neural tissue to the cervical spinal cord through a defect in the upper dorsal vertebral bodies.

The presence of the tunnel through the vertebral bodies is not essential as is evident in the cases described by Fallon, *et al.*,[3] but the readily recognizable vertebral anomalies, when found in association with intrathoracic or abdominal masses, should provide useful clues suggesting the diagnosis of enteric cyst or duplication of the foregut.

The particular group of abnormalities which we have presented is probably only one manifestation of a broad spectrum of anomalies which might conveniently be regarded as resulting from the previous existence of an accessory neurenteric or chorda canal. This may include midline dorsal dermoids, neurenteric cyst, diastematomyelia, duplication of the foregut and also such vertebral dysplasias as anterior spina bifida.[2,3,6]

SUMMARY

The neurenteric canal of Kovalevski is a normal but evanescent structure occurring during early embryologic life in association with the distal portion of the notochord. Remnants of this canal may persist. Similar, but evidently accessory, canals may form and the unobliterated remnants may give rise to anomalies of clinical significance. Four patients with a neurenteric cyst are presented in detail as examples of such a malformation. Roentgenologically, this lesion is characterized by a defect in the anterior aspect of the spine with faulty formation of the vertebrae and a mediastinal soft tissue mass. The mass may be continuous with a giant diverticulum or duplication of the intestinal tract and associated with a diaphragmatic hernia. It is suggested that diastematomyelia, midline dermoids and other anomalies represent different manifestations of this aberration of fetal development.

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Vol. 79, No. 2

THE ROENTGEN MANIFESTATIONS OF PULMONARY HYPERTENSION*

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IOWA CITY, IOWA

TWO years ago before this Society we presented a paper on primary pulmonary vascular disease with pulmonary hypertension giving both clinical and roentgenologic changes as demonstrated on plain roentgenograms and by angiocardiography. Since that time, we have been studying the roentgenograms of patients with congenital heart disease having left to right shunts, and also of patients with acquired heart disease, especially mitral stenosis in order to evaluate the pulmonary artery pressure. Although we are limiting this presentation to evaluation of pulmonary artery pressures in mitral stenosis, we are convinced that, in spite of left to right shunts, a fairly accurate appraisal of the pulmonary artery pressure can be made in congenital heart disease as well.

Radiologists should study the pulmonary vasculature as carefully as they scrutinize the lung parenchyma, or as carefully as the ophthalmologist evaluates the retinal vasculature. A systematic study of the pulmonary artery trunk, the major and peripheral divisions, and the rapidity with which the more peripheral vessels attenuate will enable the radiologist to estimate within limits the pulmonary artery pressure. Is this of any importance to the patient, the clinician, or the radiologist? We believe that it is since any information or evaluation based upon demonstrable physiologic and/or pathologic changes is the foundation upon which medical science is based.

Cardiac catheterization is an expensive, time-consuming method of estimating the pressure in the pulmonary arterial tree and is not without its inherent danger to the patient. This is not true of the roentgenographic estimation. We are all aware of the limitations of the sphygmomanometer in peripheral arterial pressure determinations, how the level of pressure varies from time to time under varying conditions of disease, emotion, posture, etc. We accept those limitations and continue to record our determinations. Are we not also justified in expecting some discrepancies to be present in our estimations of pulmonary artery pressure by roentgen means and those obtained by catheterization of the lesser circulation?

We have studied the pre- and postoperative roentgenograms of 100 cases of mitral stenosis, estimated the pulmonary artery pressure without previous knowledge of the pressures obtained at cardiac catheterization, and have compared the values obtained by each method. We have done the same with congenital heart disease having left to right shunts. Whereas there are some differences based on the amount of shunt, the incidence of septal or B-lines, the roentgen evaluation of the pulmonary artery pressure follows the same general pattern. No statistics are presented since ours do not differ materially from those reported in the literature.[1–14]

In this study we have arbitrarily divided our estimations of pulmonary artery pressures into five categories: normal (0–30 mm. Hg); 30–45 mm. Hg; 45–60 mm. Hg; 60–90 mm. Hg; and 90 mm. and higher. In all categories we have made errors in our estimations. Our failures have been studied, and, whereas we have been able to find our mistakes in some cases, there are times when no adequate explanation can be found. We are aware of the several factors that can modify the pressure obtained at catheterization, but at present we prefer to believe that the pulmonary

* From the Department of Radiology, College of Medicine, University Hospitals, Iowa City, Iowa. Presented at the Fifty-eighth Annual Meeting of the American Roentgen Ray Society, Washington, D. C., October 1–4, 1957.

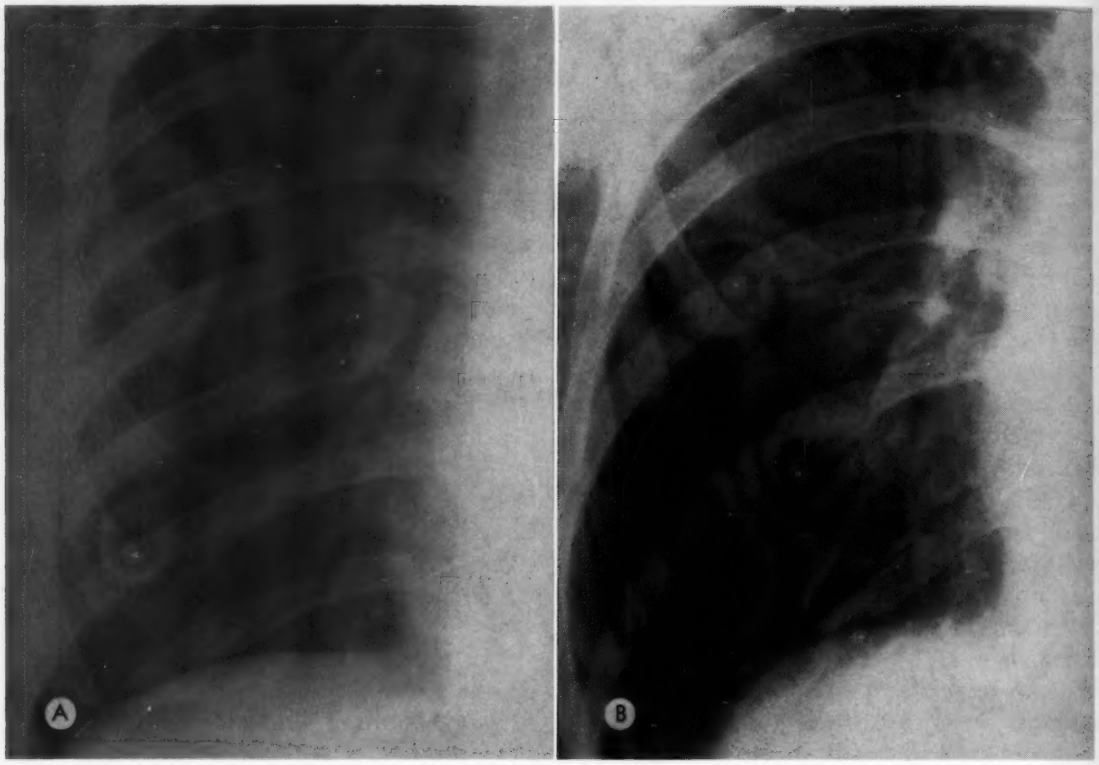

FIG. 1. (*A*) S.F., a nineteen year old female with clinical mitral stenosis, but without clinical symptoms. Pressures obtained at cardiac catheterization were: right ventricle 25/0, proximal pulmonary artery 22/9, and distal pulmonary artery 13/8. (*B*) A.A., a twenty-seven year old male with clinical mitral stenosis and with mild symptoms. Pressures were: right ventricle 30/−1, proximal pulmonary artery 25/12, and distal pulmonary artery 18/11. The division of the right pulmonary artery into its branches follows a normal, even attenuating pattern.

artery pressure is the *usual* pressure and not a response to an abnormal stimulus or a mechanic aberration. The duration of the elevated pressure is a factor which cannot be determined at this state of our knowledge.

DISCUSSION

The roentgenographic findings in pulmonary hypertension are the same regardless of the cause, *i.e.*, whether it is primary pulmonary vascular disease or secondary to such conditions as mitral stenosis, congenital heart disease with left to right shunts, pulmonary emphysema, multiple pulmonary emboli, etc. Steiner and Goodwin,[12] and Arvidsson and Ödman[2] have classified pulmonary hypertension into an active and passive category. Passive hypertension is the result of increased left auricular and pulmonary venous pressures, associated with only mild to moderate increase in pressure in the pulmonary artery. Active hypertension is the result of an increase in the pulmonary arteriolar resistance, either physiologic or pathologic, and is associated with considerable increase in pulmonary artery pressures.

In studying the roentgenograms for evidence of pulmonary hypertension, the entire vascular system must be carefully scrutinized because the heart size, the size of the hilar vessels and the more peripheral vessels when used *alone* do not mirror the level of the pressure. For reasons which are not clear, severe pulmonary hypertension in both the acquired and the congenital types may be present in a patient with a heart of normal size and hilar vessels which are only slightly increased in size. The

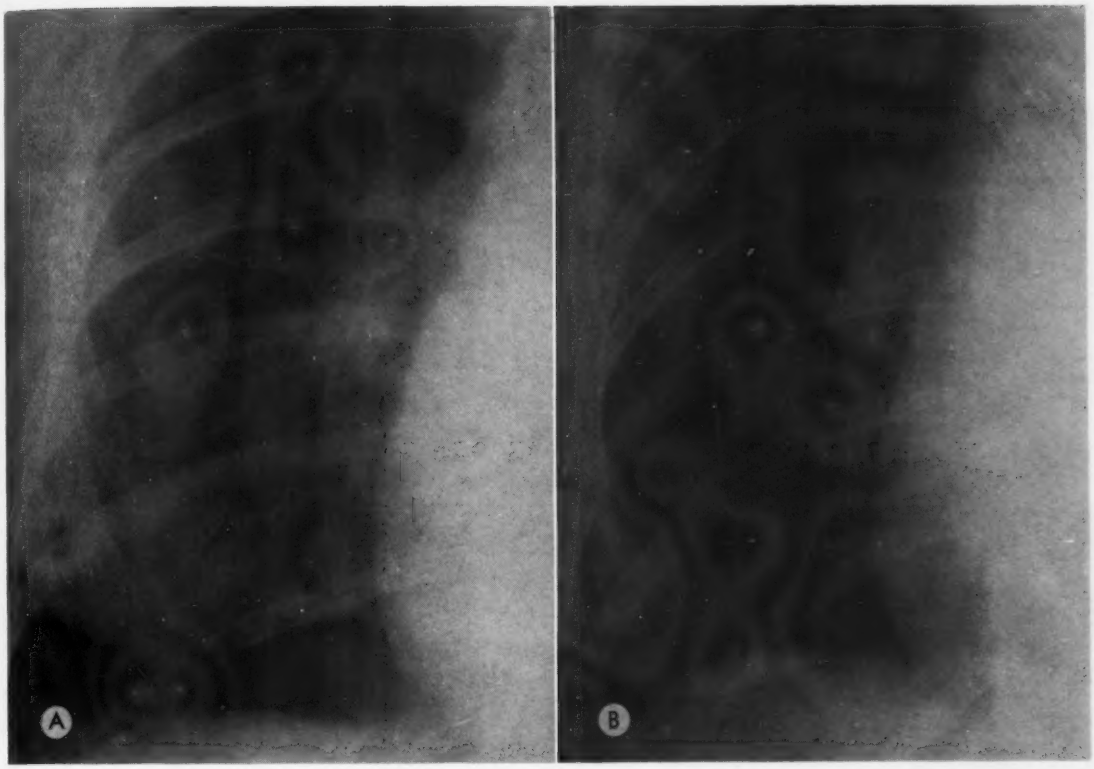

FIG. 2. (*A*) N.K., a forty-four year old female with mitral stenosis. The heart was slightly enlarged with a Danzer ratio of 0.54. The pressures were: right ventricle 48/4, proximal pulmonary artery 41/22, and distal pulmonary artery 20/15. The pulmonary artery at the hilus is slightly enlarged, but aside from a few vessels paralleling the right heart border, the branches attenuate rapidly and irregularly. In addition there are septal, or B-lines. (*B*) Postoperative roentgenogram after four months. The Danzer ratio was 0.55. The hilus is smaller, the septal lines are gone, the vessel outlines are more distinct, but the pattern has not yet returned to normal.

number of vessels which reach the periphery, especially in the bases and lateral to the hilus, is considerably diminished. Radiologists should view the plain roentgenogram as though the vessels were opacified by contrast material not just in the hilus, but to the periphery. In this manner, one will find that the normal pattern is altered in patients with pulmonary hypertension. The degree of abnormality varies in patients having approximately the same pressure readings and likewise the patients who

FIG. 3. A.H., a thirty-nine year old female with mitral stenosis. The heart was not enlarged, the Danzer ratio being 0.48. The pressures were: right ventricle 45–59/0, proximal pulmonary artery 40–46/20–25, distal pulmonary artery 21–28/15–18 and with exercise the pulmonary artery pressure went to 63/28. The pulmonary artery at the hilus is not enlarged, but the peripheral vessels attenuate rapidly in an irregular pattern, and some in the base are very small, lying next to nearly normal vessels.

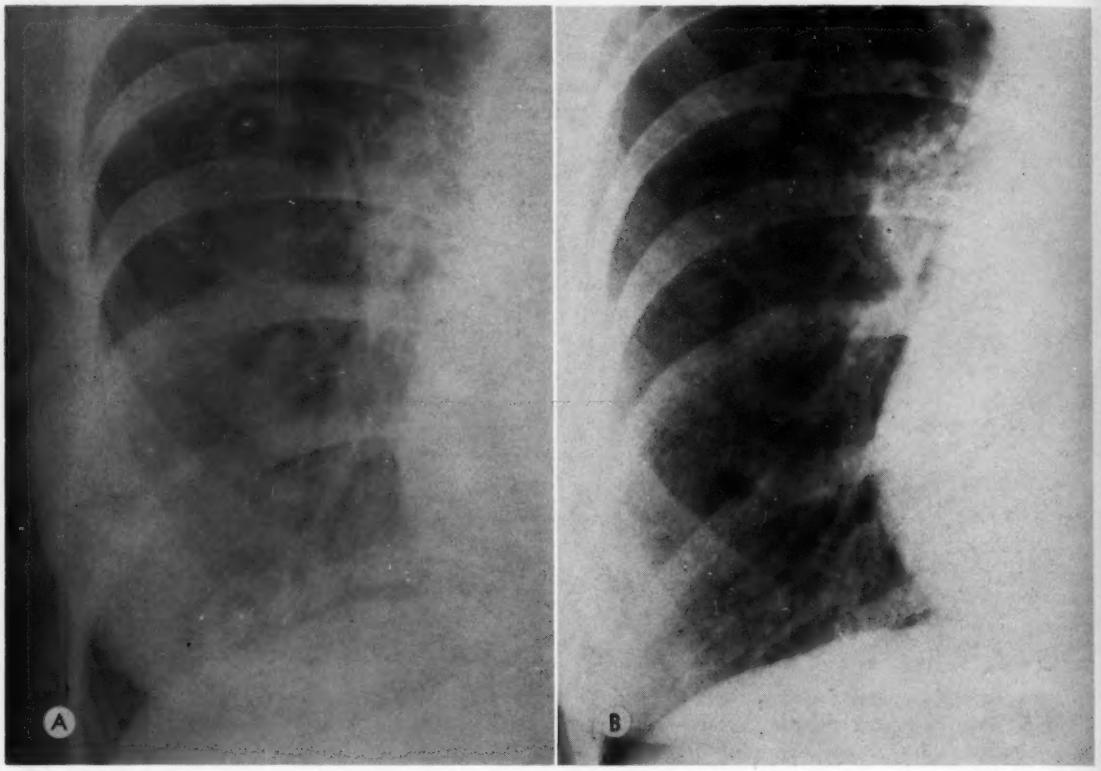

FIG. 4. (*A*) M.B., a thirty-six year old female with mitral stenosis. The heart was enlarged with a Danzer ratio of 0.57. The pressures were: right ventricle 47/3, proximal pulmonary artery 47/30, distal pulmonary artery not obtained. The pulmonary artery at the hilus is enlarged. There are irregular, tortuous, small vessels in the mid-portion of the lung, similar to those seen in the neovascularity of some of the gliomas as visualized by cerebral angiography. Septal lines are present. Ten months after surgery the pressures were: right ventricle 24–29/0–3, proximal pulmonary artery 22–27/10–14, and distal pulmonary artery 13–16/10–12. (*B*) Five years later the pulmonary vasculature, while not normal peripherally, shows lessening of the septal lines, sharper vessel outline in the middle third, and none of the fine irregular small vessels. The hilus appears of the same size.

have the same degree of mitral stenosis, as evidenced at surgery, have differences in the vascular pattern and in the degree of pulmonary hypertension. Just how much significance should be placed on the catheterization findings is debatable, since the pressures obtained represent pressures at a certain time and under certain conditions or circumstances. The estimation of the pulmonary artery pressure roentgenographically may well give a better evaluation, not specifically of the exact pressure, but of the pathologic and physiologic changes in the vessels (narrowing, rapid attenuation, neovascularity and at times irregularity in lumen) and their effect on the size of the pulmonary hilus and on the size of the heart.

Short[11] indicated that an abnormal profusion of vessels 0.5 to 2.0 mm. in diameter was responsible for the clouding of the hilar and perihilar shadows, the poor definition of the pulmonary vessel walls and bronchial lumen, and the loss of the sharp borders of the heart and ribs. He concluded that a normal lung pattern rules out severe mitral stenosis.

B-lines of Kerley or septal lines are present in moderate to severe pulmonary hypertension with mitral stenosis, but, in our opinion, do not correlate as well with pulmonary artery pressure as does the assessment of the pulmonary vasculature. If these lines are distinct, the pulmonary artery pressure is high, but high pulmonary artery pressure *per se* can and does occur

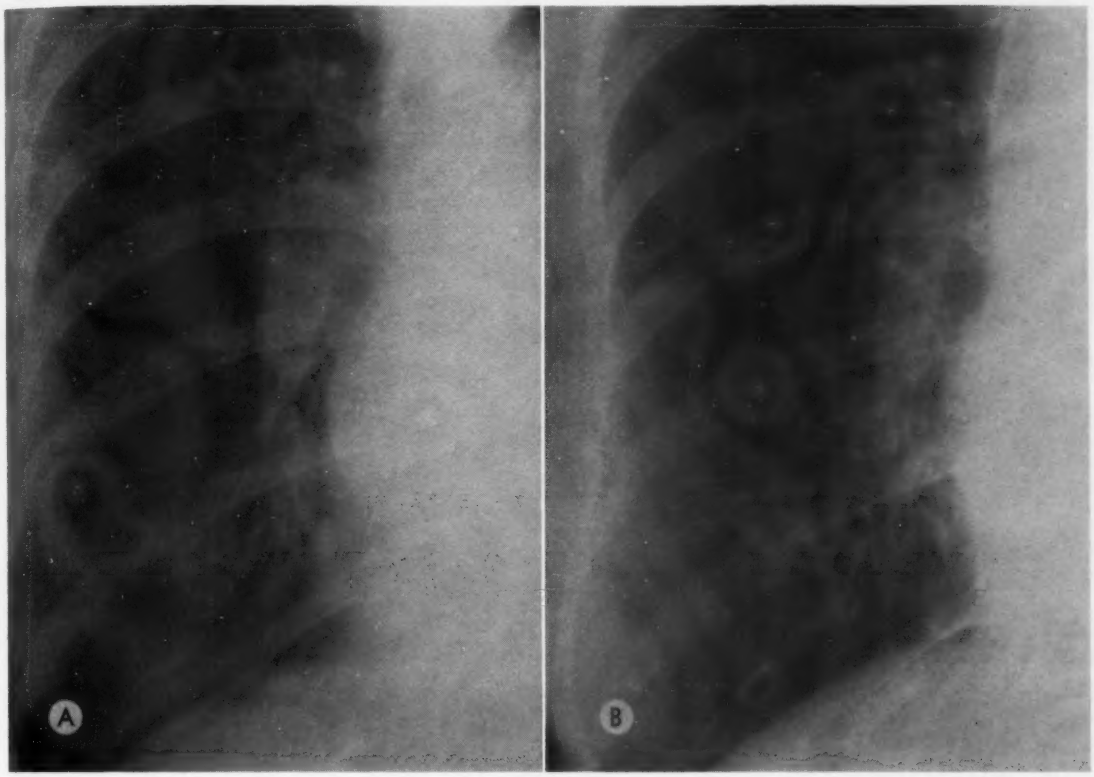

FIG. 5. (*A*) L.H., a twenty-six year old female with mitral stenosis. The heart was slightly enlarged with a Danzer ratio of 0.52. The pressures were: right ventricle 55/2, proximal pulmonary artery 48/20, and distal pulmonary artery 30/22. The hilus branch is enlarged, but there is an irregular, but rapid attenuation of the peripheral branches with irregular patches of ill-defined indistinct vessels in the mid-lung field. No septal lines are present. Ten months postoperatively the findings at catheterization were: right ventricle 40/0, proximal pulmonary artery 35/15, and distal pulmonary artery 25/12. (*B*) Roentgenogram taken thirty-eight months after surgery still shows the hilus to be slightly enlarged. There is better delineation of the vessels, although many are still irregular and still attenuate more rapidly than normal. These findings are intermixed with normal appearing vessels.

without their presence. We feel that they represent pulmonary lymphatic and/or venous engorgement, and as suggested by Rossall and Gunning[8] are indicative of increasing left atrial pressure not far below that necessary for the production of pulmonary edema. Rossall and Gunning also believe that pulmonary capillary pressure is more important than pulmonary artery pressure in the production of these lines. This would seem to be true in our cases as well. As with Keats *et al.*,[6] we were unable to find any correlation of B-lines and pulmonary hypertension in congenital heart disease with left to right shunts. We have 2 cases of congenital heart disease with left to right shunts in young women whose pulmonary artery pressures were 130 and 120 in a ventricular septal defect and an atrial septal defect, respectively. These were not associated with septal lines; there was no cardiac enlargement and the hilar vasculature was only slightly larger than normal, but both of these had considerable and rapid attenuation of the peripheral vascular pattern with relative avascularity of the lung bases. Intrapulmonary ossifications, on the other hand, when present were associated with severe pulmonary hypertension in mitral stenosis. We also have noted a frequent association of relative tricuspid insufficiency in our mitral stenosis patients having considerable elevation of the pulmonary artery pressure.

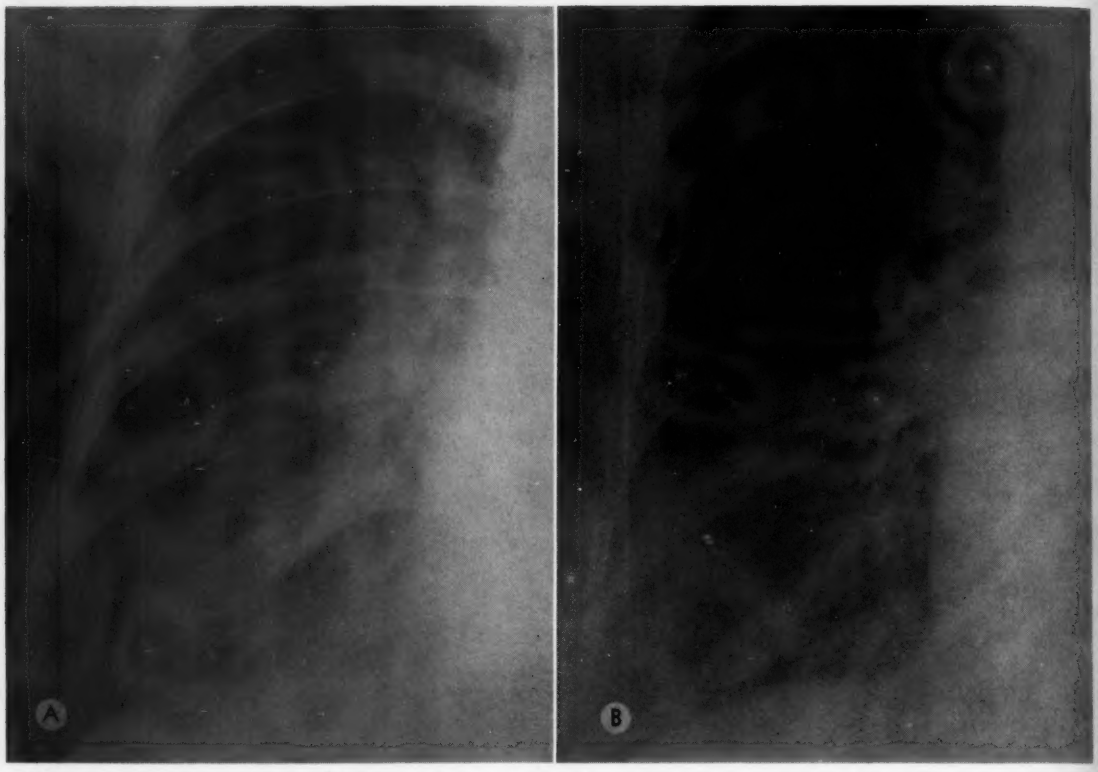

FIG. 6. (*A*) E.D., a forty-six year old female with mitral stenosis. The heart was slightly enlarged with a Danzer ratio of 0.54. The pressures were: right ventricle 75, proximal pulmonary artery 70, distal pulmonary artery not obtained. The hilus is enlarged, the vascular pattern is distorted, irregular in outline, with varying rates of attenuation being present. Postoperatively catheterization revealed the following pressures: right ventricle 40–50/0–8, proximal pulmonary artery 50/25, and distal pulmonary artery 23/12. (*B*) Roentgenogram taken nearly four years later when compared with roentgenograms taken after surgery reveals some improvement but evidence of pulmonary hypertension is still present. Septal lines are still visible, but are less prominent. The patient was reoperated upon the day after this roentgenogram was taken and a tight valve was again present.

The fact that the pulmonary hypertension is reversible would indicate that extensive permanent changes in the vessel wall have not occurred. These changes are demonstrable on plain roentgenograms when taken several months after surgery. Even those patients whose symptoms have improved but whose pressures are not significantly lowered and whose roentgenograms remain unchanged, must have as yet undetectable changes in the pulmonary vasculature which require years for change,

FIG. 7. J.P., a twenty-eight year old male. The pressures were: right ventricle 57–68, proximal pulmonary artery 67, distal pulmonary artery 40, and with exercise the pulmonary artery pressure went to 86 mm. Hg and returned to 55 in only seven minutes. The heart was not enlarged and the Danzer ratio was 0.49. The hilus is large with tortuous vessels, rapid attenuation of the peripheral vascular pattern and relative avascularity of the lower lobe. No septal lines are present.

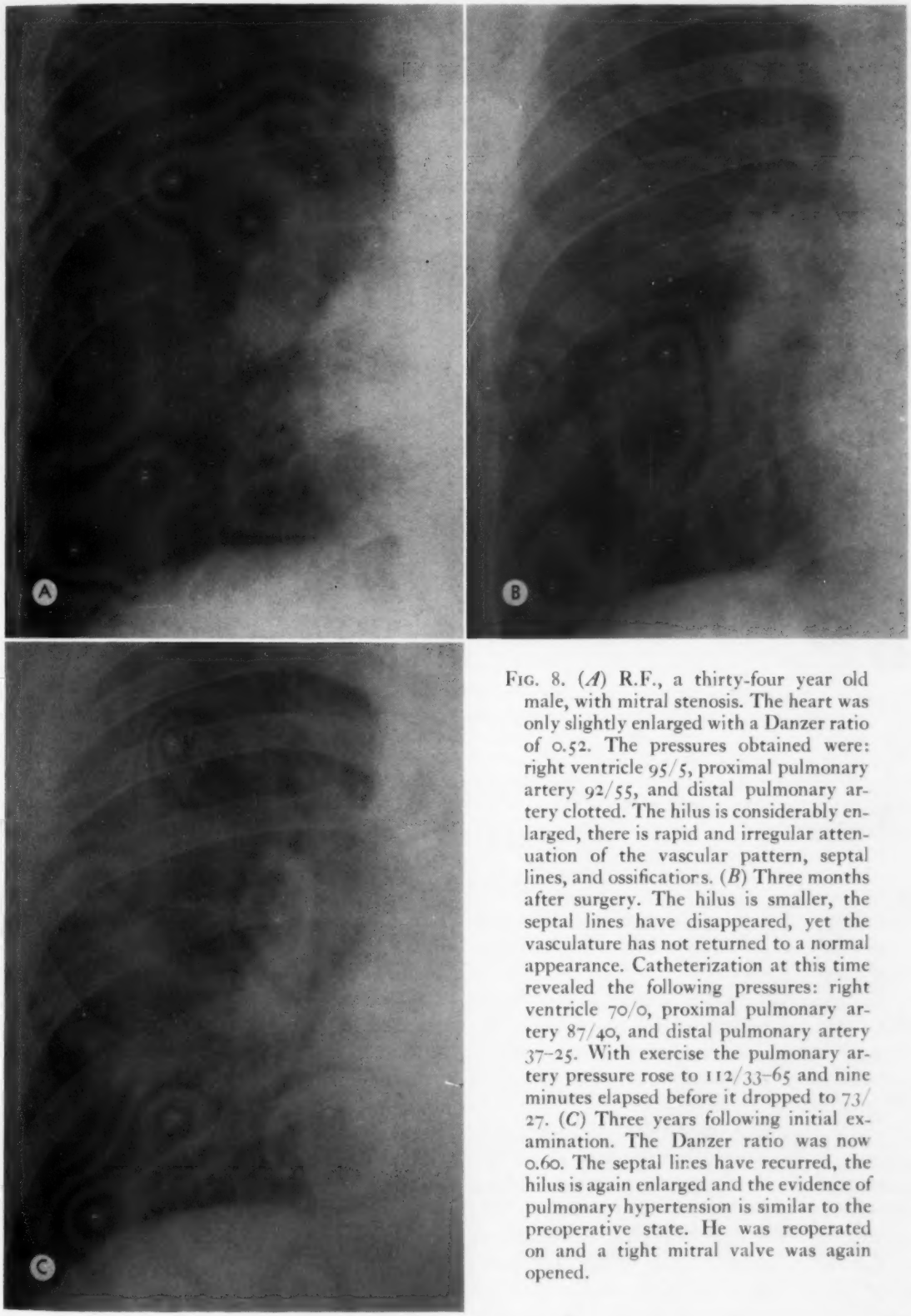

Fig. 8. (*A*) R.F., a thirty-four year old male, with mitral stenosis. The heart was only slightly enlarged with a Danzer ratio of 0.52. The pressures obtained were: right ventricle 95/5, proximal pulmonary artery 92/55, and distal pulmonary artery clotted. The hilus is considerably enlarged, there is rapid and irregular attenuation of the vascular pattern, septal lines, and ossifications. (*B*) Three months after surgery. The hilus is smaller, the septal lines have disappeared, yet the vasculature has not returned to a normal appearance. Catheterization at this time revealed the following pressures: right ventricle 70/0, proximal pulmonary artery 87/40, and distal pulmonary artery 37–25. With exercise the pulmonary artery pressure rose to 112/33–65 and nine minutes elapsed before it dropped to 73/27. (*C*) Three years following initial examination. The Danzer ratio was now 0.60. The septal lines have recurred, the hilus is again enlarged and the evidence of pulmonary hypertension is similar to the preoperative state. He was reoperated on and a tight mitral valve was again opened.

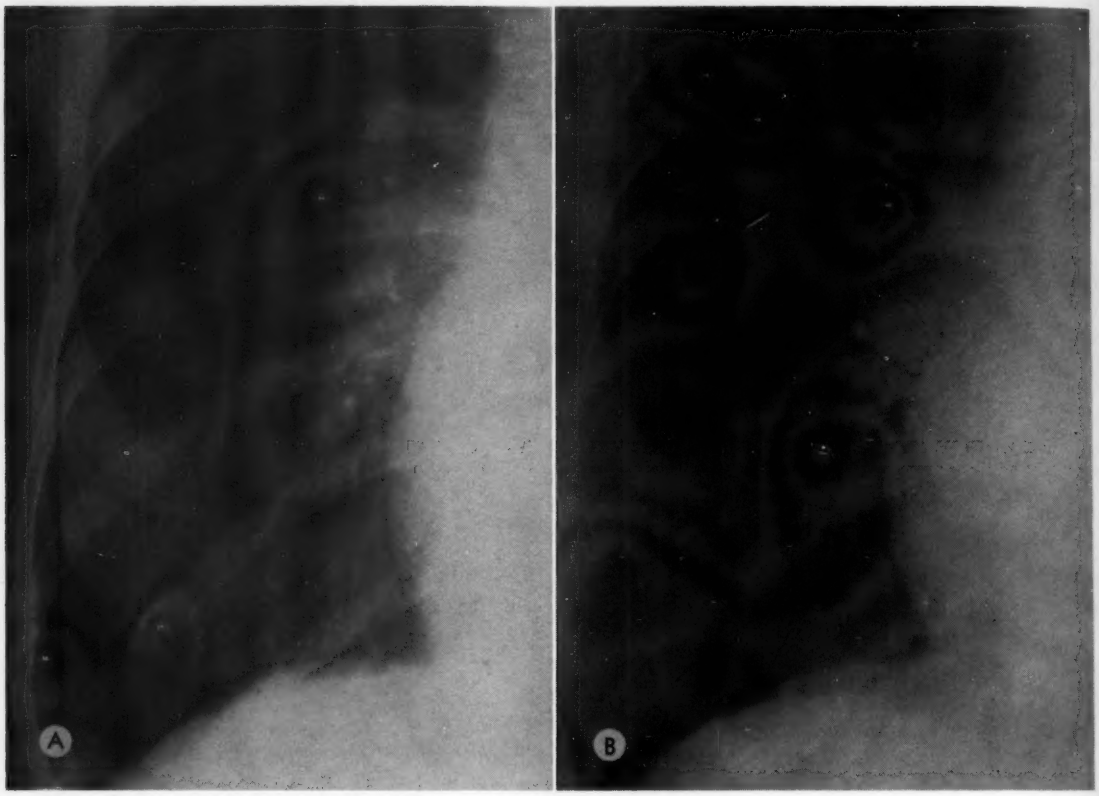

FIG. 9. (*A*) H.I., a fifty-one year old female. The heart was not enlarged, the Danzer ratio being 0.49. The pressure findings were: right ventricle 72–51, proximal pulmonary artery 90–95/50–26, distal pulmonary artery 15–22, but with exercise the pulmonary artery pressure went to 105–115/45–50. In addition, there was evidence of tricuspid insufficiency. Septal lines are present, the hilus is enlarged, the vascular pattern appears completely disrupted, irregular and attenuated. (*B*) Postoperative roentgenogram. Note absence of septal lines and the sharp margins of the vessels which are still smaller than normal. The hilus remains enlarged, however.

if any change at all occurs. Restenosis of the mitral valve again produces changes similar to those observed in the preoperative roentgenograms.

As we stated earlier, errors will occur in the exact estimation of the pulmonary artery pressure, but this should not discourage radiologists, nor should it be the cause for neglecting to assess carefully the pulmonary artery pressure on all roentgenograms. There is no other method so readily available, so moderate in cost, so lacking in inherent danger, and so reasonably accurate as a roentgenographic examination of the chest. We must accept the fact, however, that catheterization can and does give a measurement obtainable in no other way. It is accurate for the time and under the conditions at which it is taken. However, if the pulmonary artery pressure is graded into normal, moderate, and severe, and arbitrary pressures of 0–30, 30–70, and 70 and above, respectively, are used for that grading, the results will be reasonably accurate. Our clinicians found this to be true and request our opinion of the pulmonary artery pressure as evaluated from the roentgenograms not only in mitral stenosis, but also in congenital heart disease with left to right shunts.

CONCLUSIONS

1. The ravages of pulmonary hypertension can be assessed on roentgenograms of

the chest regardless of whether the cause is primary or secondary.

2. Estimation of the degree of pulmonary hypertension is reasonably accurate in pressure ranges of 0–30 mm., 30–70 mm., and 70 or over. These, then, should be graded normal, moderate, and severe.

3. Estimation of the heart size, the size of the main pulmonary arteries and their peripheral divisions, the rate of attenuation of the peripheral branches, the loss of normal sharpness of outline of the vessels, and the evidence of neovascularity are the signs upon which we depend for the evaluation of pulmonary hypertension. All must be utilized.

4. B-lines of Kerley or septal lines are, when present, indicative of impending failure although "permanent" lines may occur. They do not correlate well with the degree of pulmonary hypertension in mitral stenosis and are rare in congenital heart disease with pulmonary hypertension.

5. Relative tricuspid insufficiency was seen in patients with severe pulmonary hypertension in a high percentage of our patients.

6. Routine evaluation of the pulmonary vasculature is the easiest method of determining the pulmonary artery pressure, is safe, inexpensive, and reasonably accurate. The abnormalities present on the roentgenogram represent pathologic and/or physiologic changes, the severity and duration of which may be estimated.

7. Intrapulmonary ossifications, when present, were associated with severe pulmonary hypertension in mitral stenosis. Their presence is not indicative of pulmonary hypertension. Ossifications can occur without septal lines.

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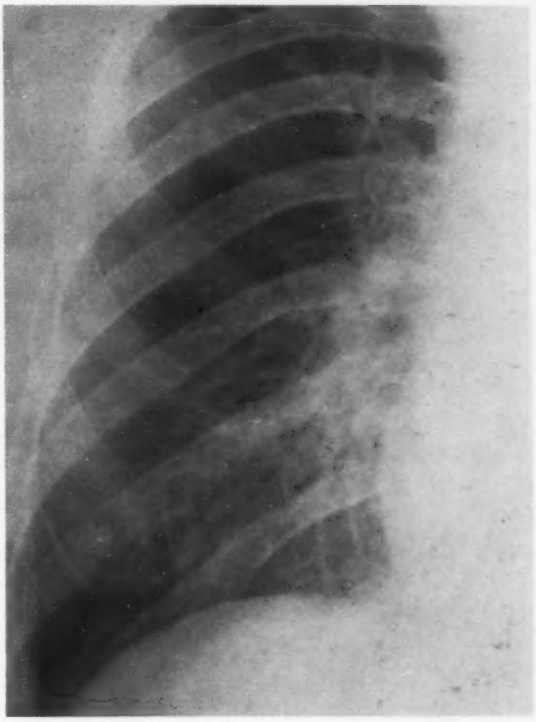

Fig. 10. M.D., a twenty-five year old female. The heart was slightly enlarged with a Danzer ratio of 0.52. It was our impression that the pulmonary artery pressure would be 40–50 mm. Hg. At catheterization, however, it was found to be as follows: right ventricle 65–77/0–7, proximal pulmonary artery 65–75/25–37, and distal pulmonary artery 0–65. The atrial pressure curve suggested a tricuspid stenosis. Whereas the hilus is enlarged, the vascular pattern attenuates in a normal way, although there is some irregularity in outline of a few smaller vessels peripherally in the mid-lung field.

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LAMINAGRAPHIC APPEARANCE OF BRONCHIECTASIS*

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LAMINAGRAPHY is a technical procedure by which a specific layer of the body may be shown clearly with blurring and loss of detail in the parts of the body above and below the plane of a desired section.

In 1921, Kieffer applied for a patent[8] on a method of laminagraphy which was termed a roentgen focusing device. He did this independently and unaware of methods which had been proposed and patented by Bocage[4] in 1922 in France. In 1930 Vallebonna[1] devised and operated the first laminagraphic apparatus. Much work has been done to improve and broaden this technique and radiology is indebted to the work of these and that of Zeidses des Plantes, Grossman, Sherwood Moore and others.

Many methods have been devised for body-section roentgenography,[9] and a number of terms have been proposed to denote these methods. The term usually refers to the motion of the tube in relation to the motion of the film, or, in some cases to the motion of the patient. Among some of the terms in use are laminagraphy, tomography, planigraphy, stratigraphy, and vertigraphy. In this paper the term laminagraphy is used to denote body section roentgenography in general.

ROENTGENOLOGIC CHANGES IN BRONCHIECTASIS

Bronchiectasis is the abnormal dilatation of a bronchus. The terms cylindrical, saccular, varicose or fusiform bronchiectasis, formerly used to describe and differentiate congenital or acquired disease, are merely descriptive, indicating the degree and type of dilatation which is present.

The roentgenologic changes which are seen in bronchiectasis are familiar to all roentgenologists.[2,3,12] Gudbjerg[7] found that 7.1 per cent of individuals will show no change. The remaining will exhibit varying findings. The typical changes are those of increased pulmonary markings in the involved area with increased peribronchial densities and honeycomb-like appearances due to areas of emphysema or superimposition of fibrotic bands. The bronchus may be visualized due to the surrounding peribronchial thickening,[6] and the bronchial marking may extend much more peripherally than is normally seen. Atelectasis, which varies from lobular to segmental or even lobar, may be present. Varying degrees of localized or generalized emphysema may be seen. Mediastinal shift may occur secondary to the atelectasis. Fibrous pleuritis may be apparent in a large percentage of cases.

Bronchiectasis is more common in the left lung than in the right and is more common in the lower lobes.[10] The most frequent site for primary bronchiectasis is the lingula and lower lobe on the left and the middle lobe on the right. It is unilateral in about half of the cases, and is confined to one lobe or one segment in about one quarter of all cases.

When bronchiectasis is seen in areas which are not commonly involved, the possibility of a lesion producing partial bronchial obstruction or other pathologic condition must be considered. It is rarely a diffuse disease of the bronchial tree and often involves a group of adjacent bronchi. Principally, it is a disease of youth in its primary form and pediatricians have often stated that diseases of adult life are not infrequently reflections of infantile pathology.

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Since the introduction of lipiodol as a medium for bronchography by Sicard and Forestier[15] in 1922, the diagnosis of bronchiectasis has been facilitated. It has been found that in the routine autopsy the incidence is from 2–3 per cent of all cases. Actually, the incidence is probably considerably higher as the gross changes of bronchiectasis are not easily recognized by the pathologist. In the sodden and collapsed postmortem specimen, the changes of the disease are not easily apparent and are difficult to demonstrate unless techniques such as those of Lindskog and Liebow[10] and others are used. The incidence, however, is on the decline due to the use of chemotherapeutic agents in severe bronchial infections.

Bronchography is the logical method of examination in a patient who is suspected of having bronchiectasis. Laminagraphy will not detract from this as a diagnostic agent but in some instances it will demonstrate the disease more clearly and bring out other features of it as well.

In the laminagraphic study of a patient, whether it be for demonstration of a hilar mass, a tuberculous cavity, or in the routine investigation of a patient with hemoptysis, the radiologist will often demonstrate the changes of bronchiectasis.

PATHOGENESIS

Much has been written on bronchiectasis and there has been considerable confusion as to its pathogenesis. This is due to the fact that there are multiple causes responsible for its production. Mallory[11] has listed the following five causes: chronic bronchial infection, bronchostenosis, pulmonary atelectasis, congenital anomalies of the bronchial tree and pneumonitis, or its end result, fibrosis.

LAMINAGRAPHIC APPEARANCE

Schinz, *et al.*[14] have stated that there are certain fundamental changes which must be present before a diagnosis of bronchiectasis may be made by laminagraphic techniques. Bronchial dilatation in itself may not be seen unless it is accompanied by peribronchial thickening or associated with atelectasis or any process which will throw the bronchi into relief. For an understanding of these factors which must be present before the diagnosis may be made, a brief review of the fundamental concepts of the pathogenesis of the disease and an application of the significant pathology will be helpful. Laminagraphic images are but reflections of the underlying pathology and the cross section appearance of the chest roentgenogram.

REPORT OF CASES

CASE 1. W.B., a sixty-four year old white coal shoveler, was admitted to the Massachusetts Memorial Hospitals complaining of a severe productive cough of eight weeks' duration. He had always enjoyed good health except for pneumonia 25 years previously. A roentgenogram of his chest (Fig. 1) on admission showed coarse peribronchial markings to both bases, with interstitial fibrosis, emphysema, pleuritis and a more peripheral extension of the bronchial markings than is normal. The bronchial

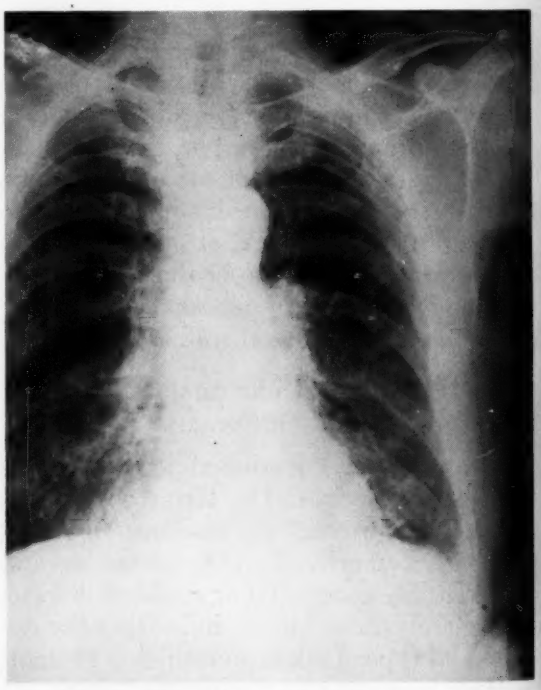

FIG. 1. Case 1. Admission chest roengtenogram showing chronic basilar pulmonary infection, interpreted as bronchiectasis.

tree was visible in some areas of involvement. Bronchograms (Fig. 2) revealed cylindrical bronchiectasis in the basal segments of the lung on both sides. Laminagrams of the pulmonary fields showed dilated and irregular bronchi (Fig. 3 and 4) with thickened walls in the areas of bronchiectasis. These bronchi, when seen in cross section, showed thick-walled circular shadows (Fig. 4).

Case II. A sixty-one year old white female was admitted to Massachusetts Memorial Hospitals for investigation of a chronic productive cough of many years' duration. A Bucky roentgenogram of the chest revealed atelectasis of the left lower lobe and this was seen as a dense retrocardiac shadow and the bronchi were seen as radiolucent streaks throughout this area (Fig. 5). A bronchogram showed atelectasis of the lower lobe and numerous cylindrical bronchial dilatations (Fig. 6). Lateral laminagrams of the left lung revealed collapse of the lower lobe and honeycombing of the collapsed segments due to bronchiectasis. There was in addition a pleural cyst or bleb adjacent to the area of collapse (Fig. 7 and 8).

Case III. E.P., a thirty-seven year old white

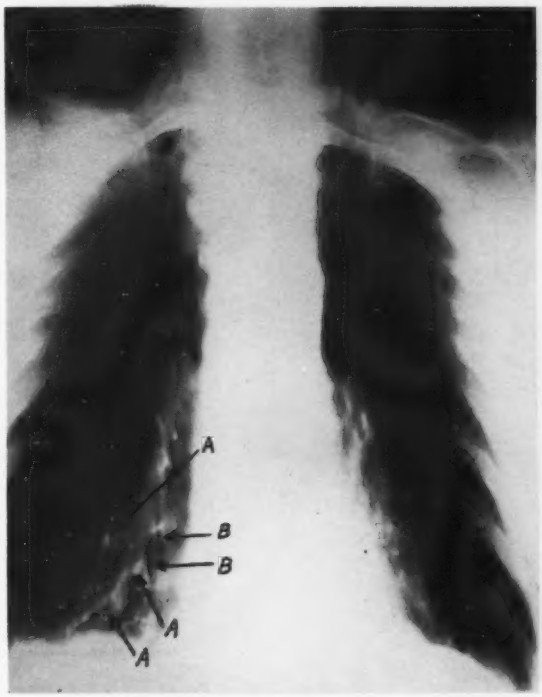

Fig. 3. Case I. A—Cross sections of thick-walled bronchi. B—Sagittal or oblique sections of the irregular, thick-walled and dilated bronchi.

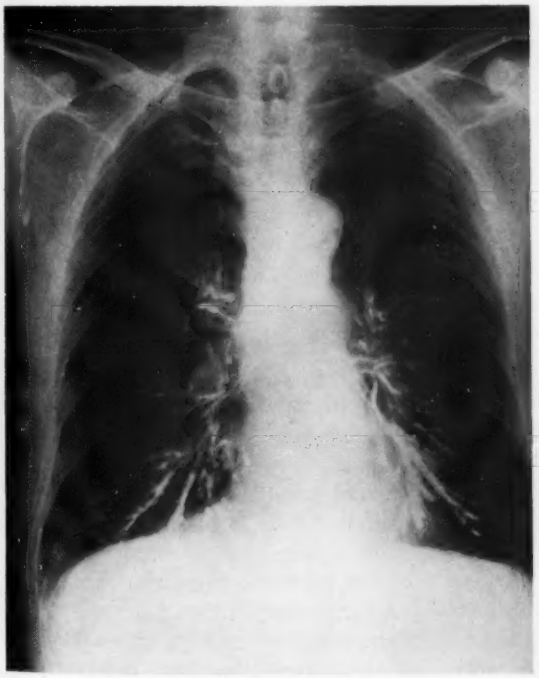

Fig. 2. Case I. Bronchogram demonstrating the basal, cylindrical bronchiectasis.

Fig. 4. Case I. Thick-walled basal bronchiectasis.

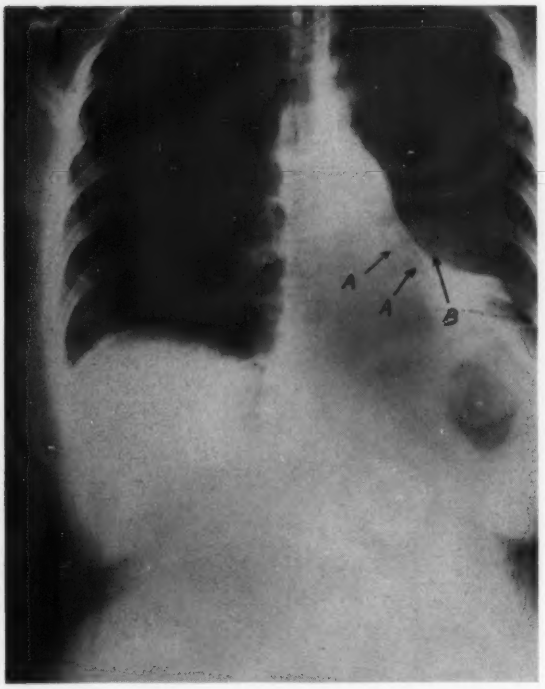

FIG. 5. Case II. Retrocardiac density with radiolucent streaks. Lower lobe atelectasis with bronchiectasis.

FIG. 6. Case II. Bronchogram demonstrating the lower lobe bronchiectasis. There is also some inadvertent filling on the right.

FIG. 7. Case II. Lateral laminagram revealing the lower lobe collapse with honeycombing due to bronchiectasis. The pleural cyst is seen posterior to the area of collapse.

female, was referred to Massachusetts Memorial Hospitals for laminagraphy to study an area of infiltration in her right apex. On plain roentgenography of the chest cavitation could not be demonstrated. Her sputum had continued positive. Laminagrams (Fig. 9 and 10) of the chest showed irregular dilated and elongated bronchi in the apical posterior segment of the right upper lobe. No cavitation could be demonstrated on multiple laminagraphic sections.

CASE IV. A ten year old girl was admitted to Massachusetts Memorial Hospitals for investigation. Six months previously she had been treated for a right upper lobe pneumonia, and this had failed to show complete clearing. In addition, she had complained of a productive cough since that time. Bronchography (Fig. 11) of the right upper lobe revealed numerous areas of saccular bronchiectasis and the vague outlines of a pulmonary cyst. Laminagraphy (Fig. 12) demonstrated the pulmonary cyst adjacent to the right hilus and surrounding this cyst numerous bronchial dilatations in the form of thick-walled oval and circular shadows.

FIG. 8. Case II. Enlargement of the involved area, the arrows pointing to the dilated bronchi.

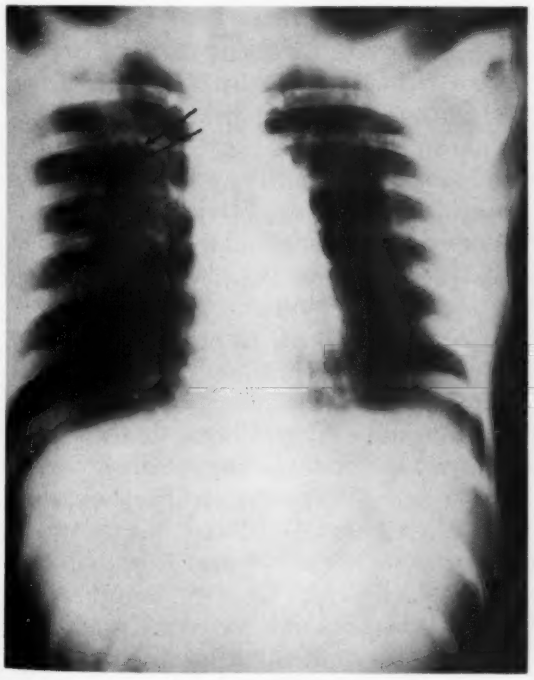

FIG. 9. Case III. Bronchiectasis in the apical posterior segment, probably the source of continued infection.

FIG. 10. Case III. Enlargement of Figure 9 to demonstrate the bronchiectasis more clearly.

FIG. 11. Case IV. Bronchogram demonstrating the saccular bronchiectasis in the right upper lobe.

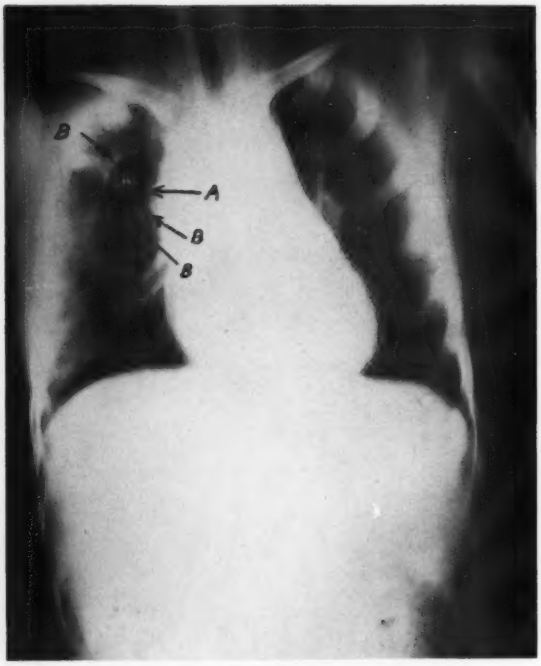

FIG. 12. Case IV. Laminagram showing the pulmonary cyst (A) surrounded by bronchiectasis (B).

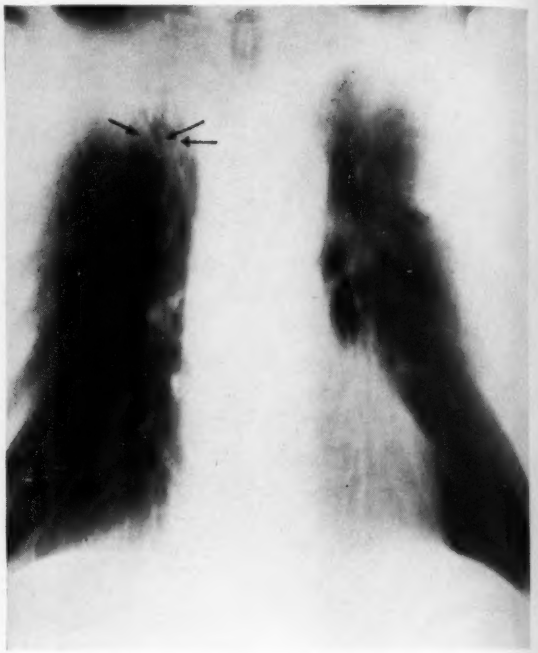

FIG. 13. Case V. Laminagram revealing the apical fibrotic infection with dilated bronchi (arrows) in the apical segment of the right upper lobe.

CASE V. A fifty-six year old male with a history of sanatorium treatment for tuberculosis was admitted to Massachusetts Memorial Hospitals because of hemoptysis. Roentgenograms of the chest revealed an old right apical scarring. Laminagrams of this area showed thick-walled dilated bronchi in the region of the apical streaking. The patient was operated upon and the diseased lung resected. The pathologic examination revealed chronic fibrotic tuberculosis with no evidence of cavity. There was extensive tuberculous bronchiectasis.

DISCUSSION

All of the conditions described by Mallory are demonstrable by laminagraphy, and when these are found by laminagraphy, the underlying changes of bronchiectasis should be searched for.

Bronchial Infection. This often results in destruction of the bronchial wall with marked distortion. The bronchial wall is thickened, stiffened, and may show varying alterations in its caliber, from beading to cylindrical or saccular dilatation. The bronchi appear on the laminagram as thick-walled, circular shadows when seen in cross section. When they are seen in sagittal or oblique section, they stand out as linear streaks of radiolucency. They are best seen in the hilar and parahilar regions, but the walls of the bronchi distal to the second division are no longer demonstrable. This is due to the normal decreasing caliber of the bronchus. When there is an absence of bronchial thickening, bronchiectasis is not visualized, but occasionally small areas of emphysema or fine peripheral reticulation representing emphysema are observed.

Atelectasis. When atelectasis is present the changes are dependent upon the degree of atelectasis. If the atelectasis is small and peribronchial in position, the bronchi stand out in relief, and the ectatic bronchus may be seen. When the atelectasis is more marked, segmental or lobar in extent, the dilated bronchi may appear as radiolucent streaks in the atelectatic segment or in the form of a honeycomb pattern. In addition to visualization of the bronchi, the vessels may be seen, as are the bronchi, more closely approximated than normally, due to atelectasis.

Bronchostenosis. When there is bronchostenosis, secondary to tumor or other

causes producing incomplete bronchial obstruction, the bronchi may be seen distal to the point of stenosis. When complete bronchial stenosis has supervened, bronchiectasis may occasionally be demonstrated in the atelectatic segment.

Congenital Anomalies. Congenital anomalies of the bronchial tree are occasionally associated with bronchiectasis. When there is arrested development of the bronchopulmonary segments, the more peripheral portions of the bronchus may become secondarily infected and bronchiectatic. Occasionally, pulmonary cysts of the lung may be seen associated with bronchiectasis, suggesting that there is either some relationship to development or that the bronchiectasis is secondary to a degree of bronchial obstruction produced by the cysts. In either instance the changes seen are those of peribronchial thickening associated with the pulmonary cyst or the aborted development of the bronchial tree.

Pneumonitis. Pneumonitis and fibrosis as factors in bronchiectasis are best demonstrated in the study of apical tuberculosis. Patients who are studied by laminagraphy in the search for cavitation as the cause for positive sputa will occasionally reveal no evidence of cavitation. Instead, dilated bronchi are seen. These may act as cavities and continue to enhance the progress of the disease.

In patients with chronic fibrotic tuberculosis, the dilated bronchi may appear as tubular radiolucent streaks in the area of disease. When there is gross distortion and abnormal angulation of the bronchi, tuberculosis is the most likely etiology.[13] It should be stated that all bronchiectases are potential reservoirs for disease, but that activity of disease should not be attributed to them until cavitation is definitely excluded. Many of these are epithelialized bronchi secondarily dilated by scarring produced by the disease. When cavitation is present, the bronchus leading from the cavity to the hilus may be seen as thick-walled dilated bronchus.

SUMMARY

In the investigation of a patient for disease of the lungs laminagraphy is often used. It is not unusual to find the laminagraphic signs of bronchiectasis in many of these patients, consisting of dilated, irregular and thick-walled bronchi which may be seen either in sagittal, oblique or cross section. Whenever the conditions necessary for the development of bronchiectasis are present, as they are in chronic inflammation, bronchostenosis, atelectasis, fibrosis, or congenital bronchial malformations, bronchiectasis should be searched for.

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GROSS ANATOMICO-SPATIAL CHANGES OCCURRING IN LOBAR COLLAPSE*

A DEMONSTRATION BY MEANS OF THREE-DIMENSIONAL PLASTIC MODELS

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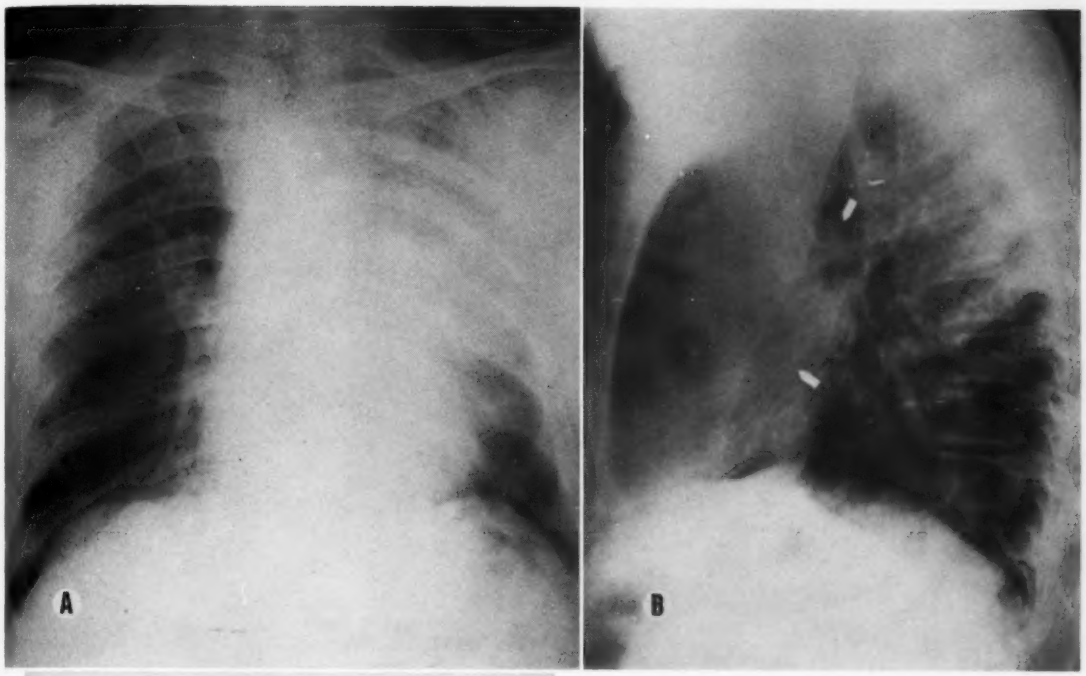
IN 1951 we presented, in some detail, the roentgen patterns of lobar collapse,[1] with emphasis on the appearance in the lateral projection. In that paper we explained the mechanism of collapse in the various lobes, using line diagrams to illustrate the direction and mode of shift of a collapsing lobe. An attempt was also made, by diagram, to illustrate the change in the shape of a collapsing lobe from a three-dimensional pyramidal structure, towards a flat, almost two-dimensional triangle.

By now, the roentgen appearance of lobar collapse is well known, but there still remains considerable confusion about the changes in shape, the direction of shift of the collapsing lobe and the rearrangement of the spatial relationships that produce these roentgen findings. Judging by correspondence we have received and by conversations with many radiologists, the diagrams we published fell short of explaining clearly these basic gross pathologic changes —apparently because the diagrams lacked a three-dimensional effect. Many correspondents betrayed their lack of understanding by the very questions they asked.

Therefore, we decided to try to illustrate the actual anatomico-spatial changes by means of three-dimensional models. By making these models of transparent and translucent plastic material, the effect of a penetrating roentgen ray could be simulated. The models could then be viewed from different angles and compared with roentgenograms in different projections. This, we thought, would be of especial value in correlating the appearance seen

FIG. 1. *Normal Lung.* Lateral aspect of normal left lung, executed in transparent Plexiglas; all other models are shown in comparable fashion. In other models the collapsing lobe is made of white translucent Plexiglas, whereas the normal or over-expanded remaining lobe(s) is made of transparent Plexiglas. Thus, one sees through the model as the roentgen-ray tube "sees" through the lung. Each model is shown with the posteroanterior and lateral views of a case showing the roentgen appearance of that degree of collapse. In each instance the lateral view should be compared with the photograph of the model to understand the spatial changes which cause the roentgen appearance.

* From the Department of Radiology, Mount Sinai Hospital of Cleveland and the Radiologic Group of Drs. Mahrer, Krause, Lubert, Berman and Bennett.



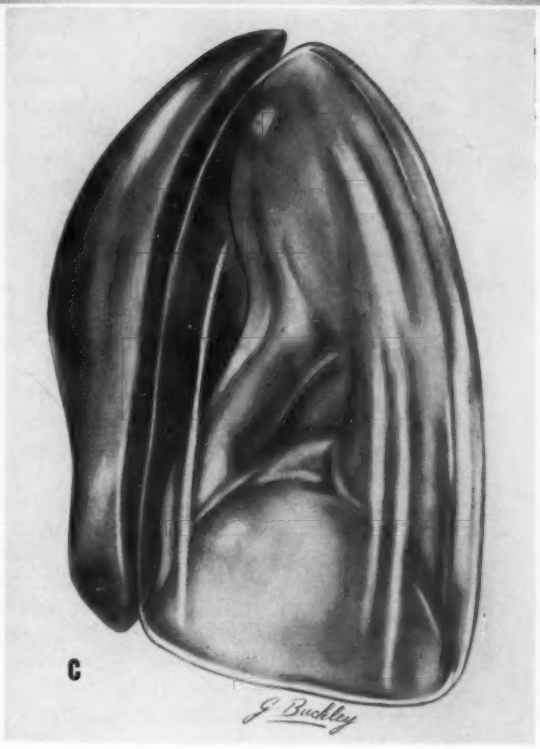


FIG. 2. *Minimal Collapse—Left Upper Lobe.* (*A*) Posteroanterior view showing slight collapse but marked atelectasis, due to bronchial block by carcinoma. (*B*) Lateral view. The more dense collapsing lobe has pivoted anteriorly and is sharply demarcated by the more vertically positioned interlobar fissure. Arrows point to hilar attachment of left upper lobe (mediastinal wedge) exposed by forward shift of fissure. (*C*) Model. The model explains the roentgen appearance of the lateral view. Note that the collapsing lobe has shifted anteriorly and has exposed the hilar attachment or lung root as a triangular shadow such as marked by arrows in *B*.

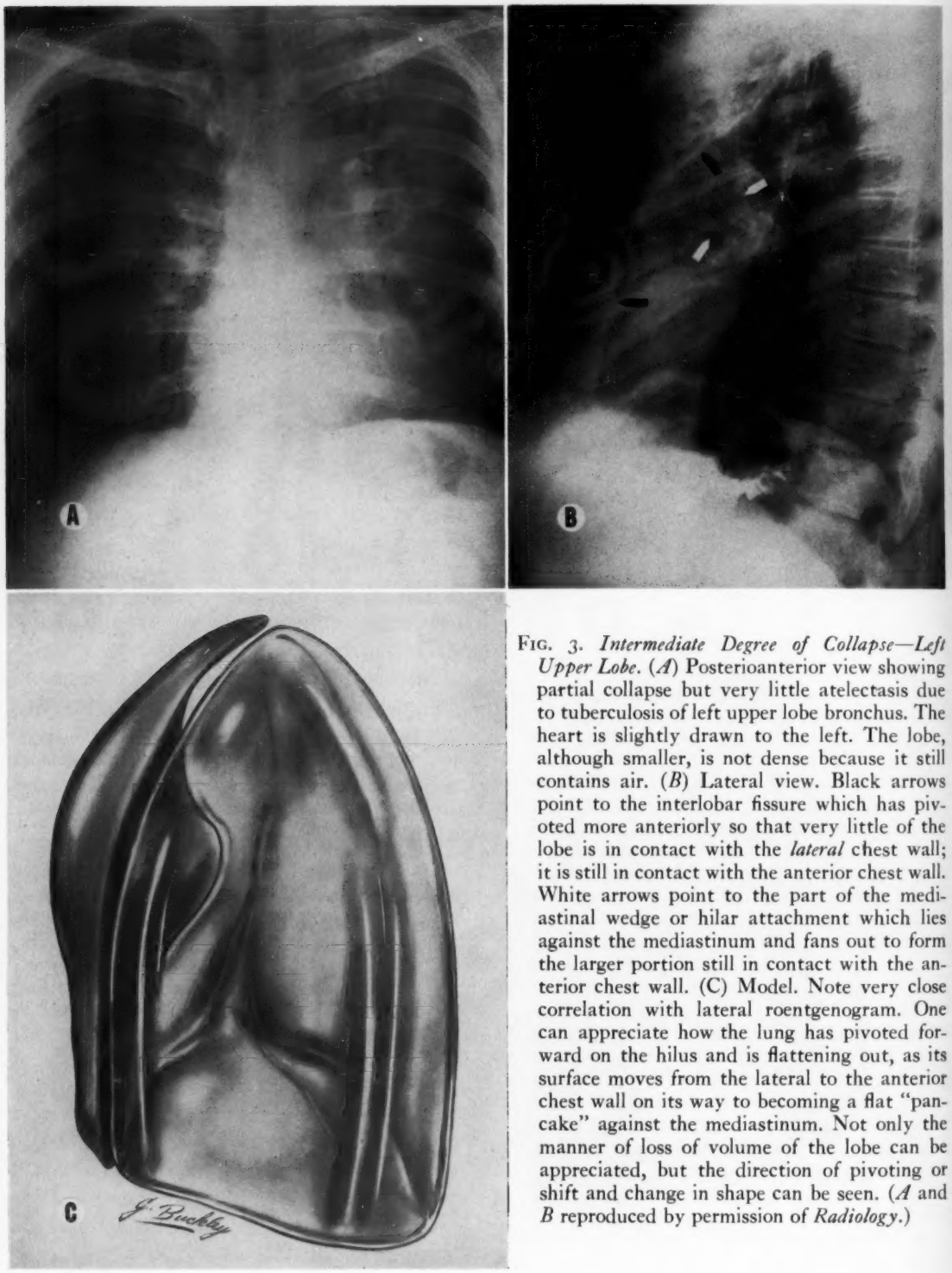


FIG. 3. *Intermediate Degree of Collapse—Left Upper Lobe.* (*A*) Posterioanterior view showing partial collapse but very little atelectasis due to tuberculosis of left upper lobe bronchus. The heart is slightly drawn to the left. The lobe, although smaller, is not dense because it still contains air. (*B*) Lateral view. Black arrows point to the interlobar fissure which has pivoted more anteriorly so that very little of the lobe is in contact with the *lateral* chest wall; it is still in contact with the anterior chest wall. White arrows point to the part of the mediastinal wedge or hilar attachment which lies against the mediastinum and fans out to form the larger portion still in contact with the anterior chest wall. (C) Model. Note very close correlation with lateral roentgenogram. One can appreciate how the lung has pivoted forward on the hilus and is flattening out, as its surface moves from the lateral to the anterior chest wall on its way to becoming a flat "pancake" against the mediastinum. Not only the manner of loss of volume of the lobe can be appreciated, but the direction of pivoting or shift and change in shape can be seen. (*A* and *B* reproduced by permission of *Radiology*.)

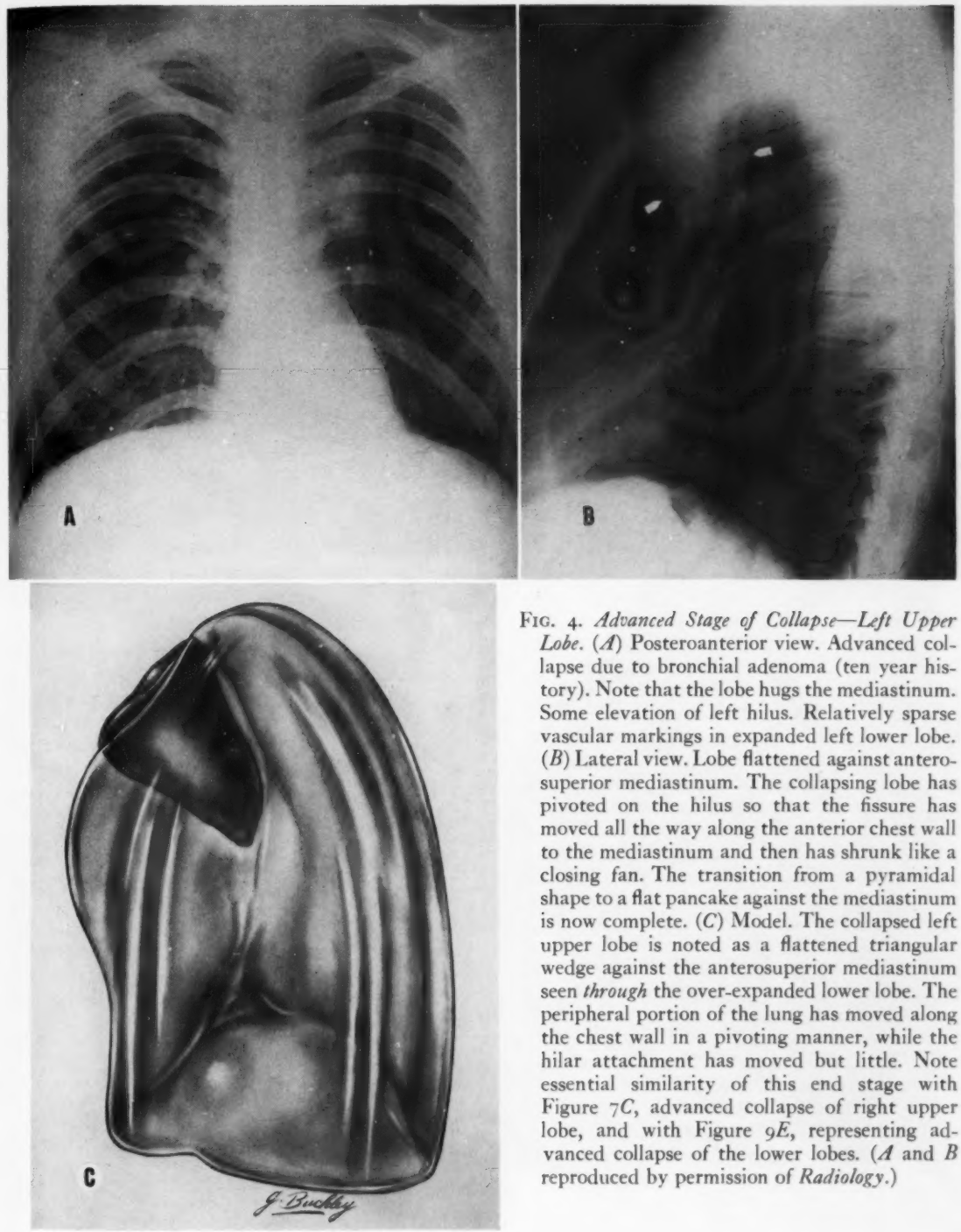


Fig. 4. *Advanced Stage of Collapse—Left Upper Lobe.* (*A*) Posteroanterior view. Advanced collapse due to bronchial adenoma (ten year history). Note that the lobe hugs the mediastinum. Some elevation of left hilus. Relatively sparse vascular markings in expanded left lower lobe. (*B*) Lateral view. Lobe flattened against anterosuperior mediastinum. The collapsing lobe has pivoted on the hilus so that the fissure has moved all the way along the anterior chest wall to the mediastinum and then has shrunk like a closing fan. The transition from a pyramidal shape to a flat pancake against the mediastinum is now complete. (*C*) Model. The collapsed left upper lobe is noted as a flattened triangular wedge against the anterosuperior mediastinum seen *through* the over-expanded lower lobe. The peripheral portion of the lung has moved along the chest wall in a pivoting manner, while the hilar attachment has moved but little. Note essential similarity of this end stage with Figure 7*C*, advanced collapse of right upper lobe, and with Figure 9*E*, representing advanced collapse of the lower lobes. (*A* and *B* reproduced by permission of *Radiology*.)

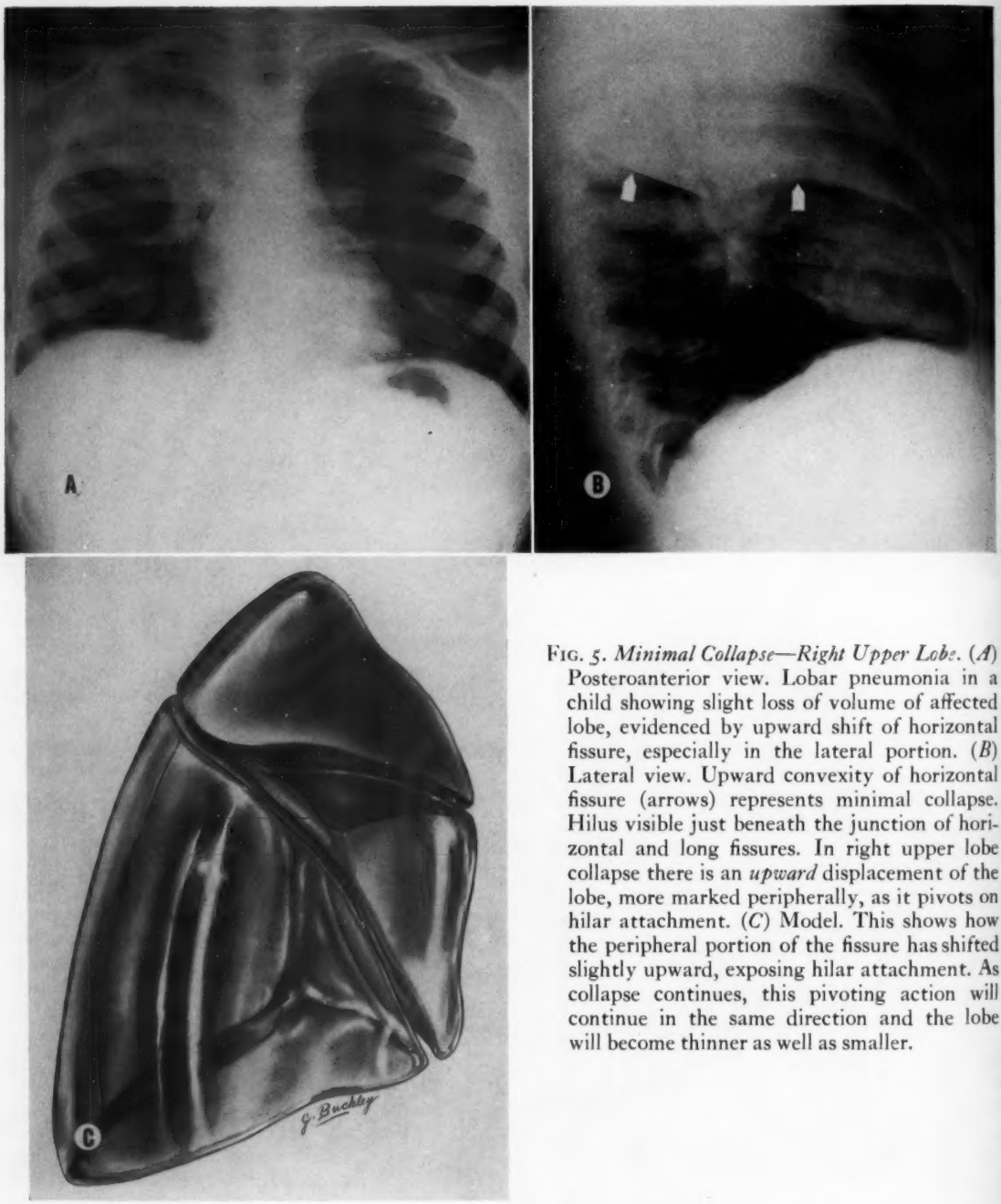


FIG. 5. *Minimal Collapse—Right Upper Lobe.* (*A*) Posteroanterior view. Lobar pneumonia in a child showing slight loss of volume of affected lobe, evidenced by upward shift of horizontal fissure, especially in the lateral portion. (*B*) Lateral view. Upward convexity of horizontal fissure (arrows) represents minimal collapse. Hilus visible just beneath the junction of horizontal and long fissures. In right upper lobe collapse there is an *upward* displacement of the lobe, more marked peripherally, as it pivots on hilar attachment. (*C*) Model. This shows how the peripheral portion of the fissure has shifted slightly upward, exposing hilar attachment. As collapse continues, this pivoting action will continue in the same direction and the lobe will become thinner as well as smaller.

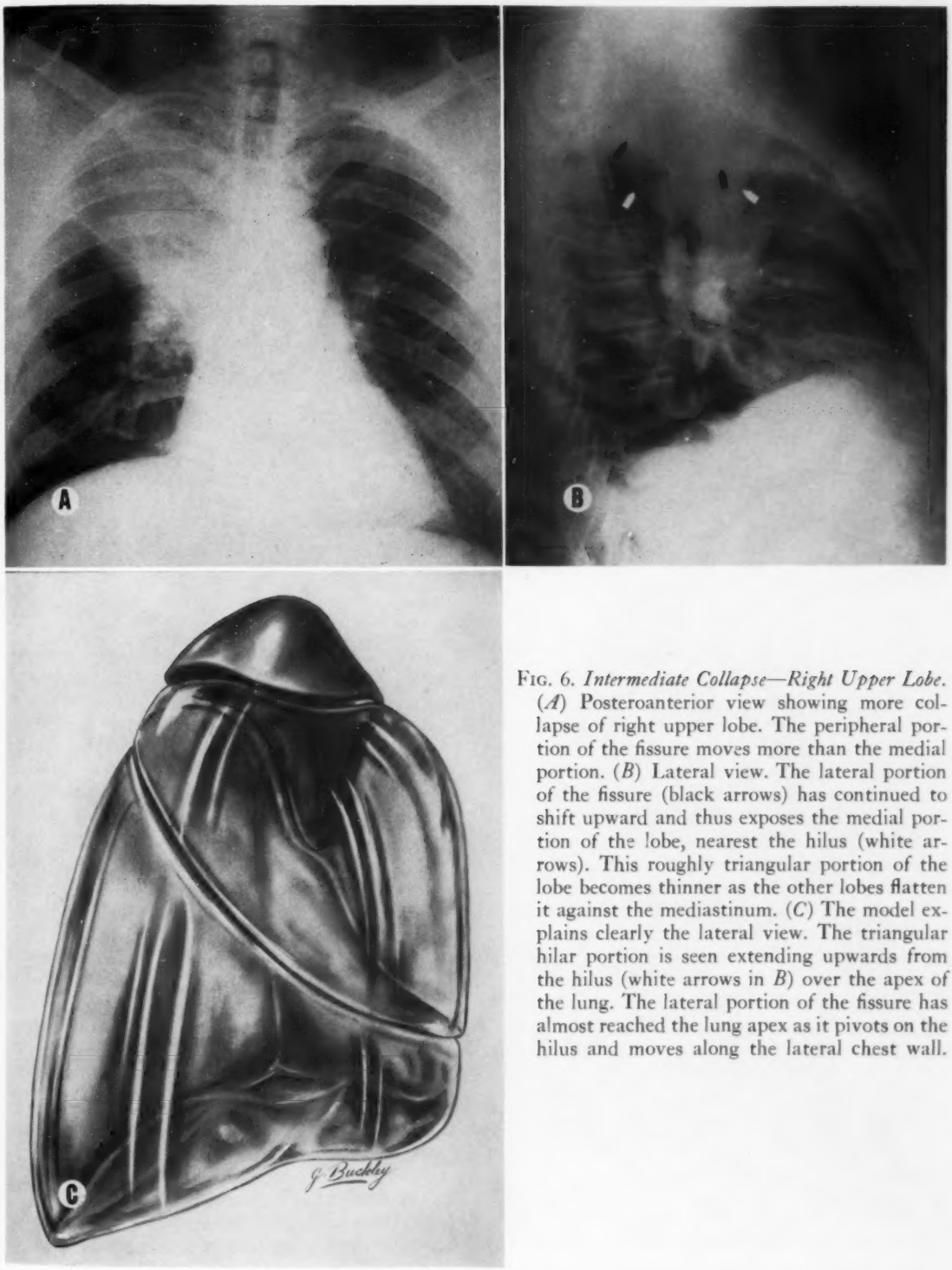


Fig. 6. *Intermediate Collapse—Right Upper Lobe.* (*A*) Posteroanterior view showing more collapse of right upper lobe. The peripheral portion of the fissure moves more than the medial portion. (*B*) Lateral view. The lateral portion of the fissure (black arrows) has continued to shift upward and thus exposes the medial portion of the lobe, nearest the hilus (white arrows). This roughly triangular portion of the lobe becomes thinner as the other lobes flatten it against the mediastinum. (*C*) The model explains clearly the lateral view. The triangular hilar portion is seen extending upwards from the hilus (white arrows in *B*) over the apex of the lung. The lateral portion of the fissure has almost reached the lung apex as it pivots on the hilus and moves along the lateral chest wall.

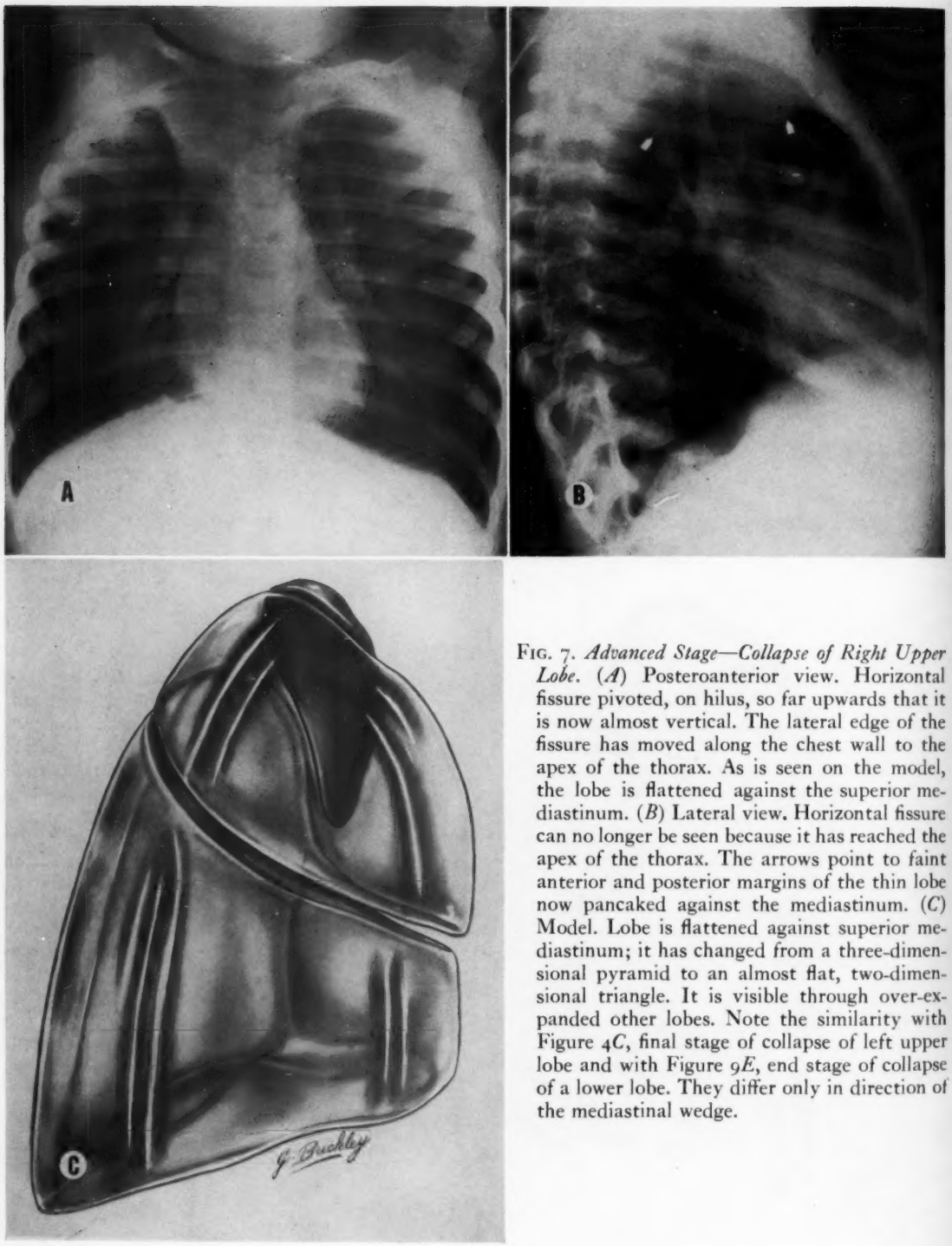


FIG. 7. *Advanced Stage—Collapse of Right Upper Lobe.* (*A*) Posteroanterior view. Horizontal fissure pivoted, on hilus, so far upwards that it is now almost vertical. The lateral edge of the fissure has moved along the chest wall to the apex of the thorax. As is seen on the model, the lobe is flattened against the superior mediastinum. (*B*) Lateral view. Horizontal fissure can no longer be seen because it has reached the apex of the thorax. The arrows point to faint anterior and posterior margins of the thin lobe now pancaked against the mediastinum. (*C*) Model. Lobe is flattened against superior mediastinum; it has changed from a three-dimensional pyramid to an almost flat, two-dimensional triangle. It is visible through over-expanded other lobes. Note the similarity with Figure 4*C*, final stage of collapse of left upper lobe and with Figure 9*E*, end stage of collapse of a lower lobe. They differ only in direction of the mediastinal wedge.

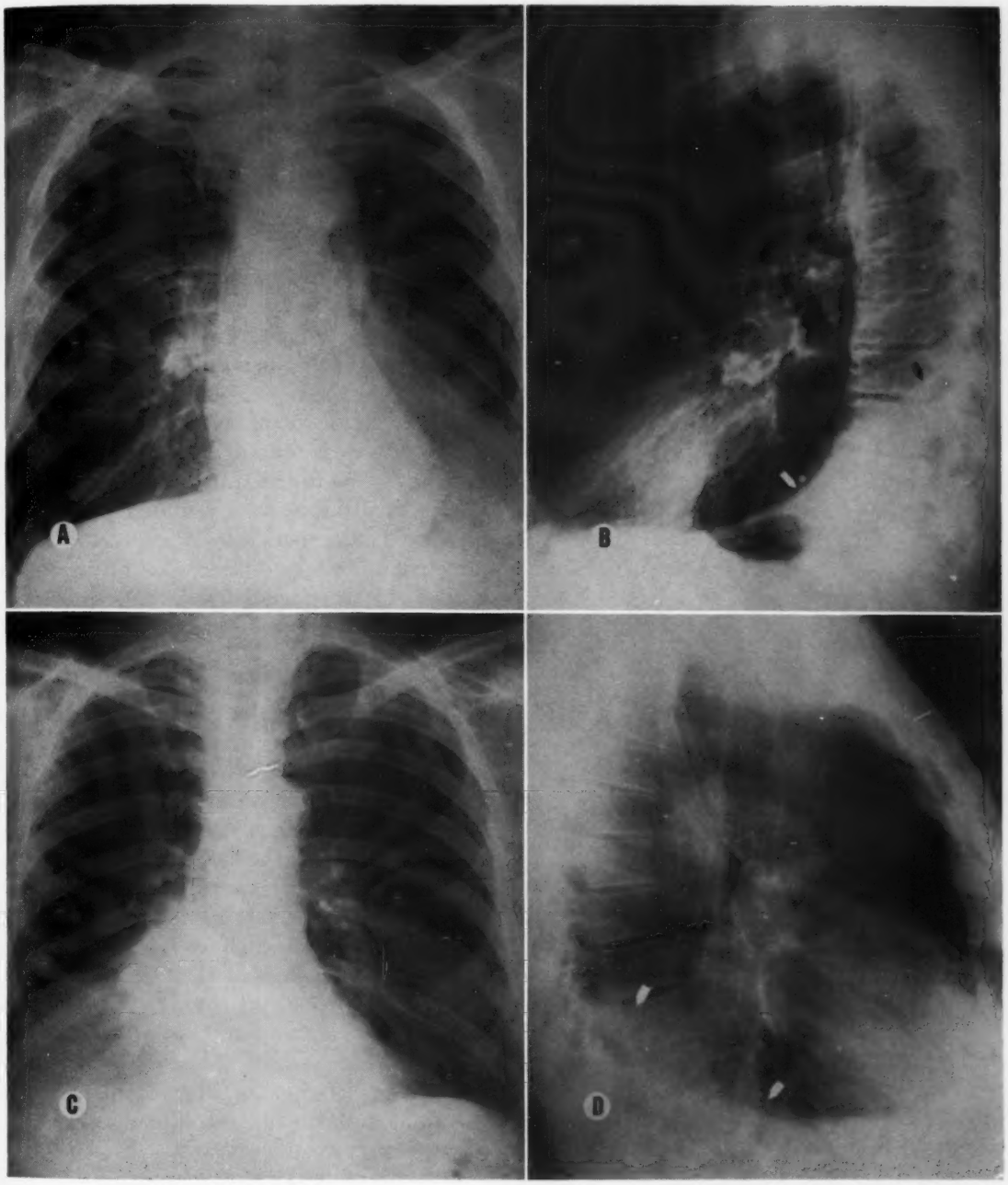


Fig. 8. *Intermediate Degree of Collapse—Lower Lobe.* (*A*) Posteroanterior view. Partial collapse of left lower lobe due to carcinoma. Hazy, poorly demarcated density behind and lateral to the heart. (*B*) Lateral view of *A*. Interlobar fissure (arrows) has shifted downwards and backwards towards the posterior costophrenic angle. Triangular mediastinal wedge not well seen because roentgenogram was overexposed. (*C*) Posteroanterior view. Partial collapse of right lower lobe due to carcinoma. Diffuse haziness in right lower lung field. (*D*) Lateral view of *C*. Black arrows outline the mediastinal wedge, *i.e.*, that part of lobe closest to the hilus and flattened against the postero-inferior mediastinum by other expanding lobes. Apex of the wedge is at hilus. White arrows point to the interlobar fissure which has pivoted posteriorly and inferiorly along lateral chest wall. Note mirror-image similarity to collapse of left lower lobe and compare with model (Fig. 8*E*).

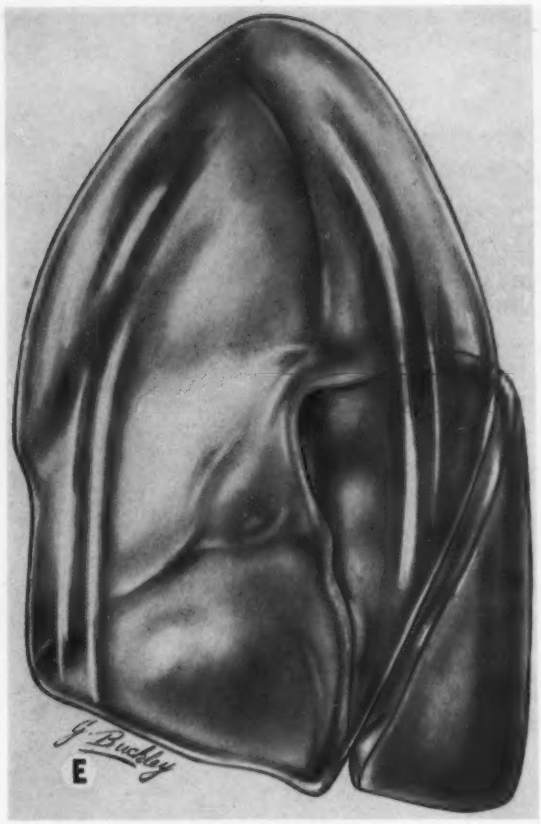


FIG. 8. (*E*) Model. Shown here as collapse of left lower lobe but the appearance in the lateral view is same for both lower lobes (Fig. 8, *B* and *D*). Mechanism and direction of collapse of the lower lobes are the same. The lobe moves posteriorly and inferiorly as it pivots on the hilus. As the fissure moves in this manner, the triangular mediastinal wedge becomes visible in the lateral view. The portion of the lower lobe behind the fissure is still in contact with the lateral chest wall and posterior costophrenic sinus.

in the posteroanterior and lateral roentgenograms. It was our hope that such plastic models could be made available through commercial channels, as a teaching aid.

PROCEDURE

Master molds of plaster were made of commercially available plaster models of each lung. These molds were a little larger than life size. The mold was filled with modeling clay and a clay replica of the human lung obtained.

The clay lung was then cut and shaped into its component lobes and cast in plaster. From these plaster models of each lobe, heat-stable, reciprocal molds of dental plaster were made for each surface. These molds were heated to about 160° F.; Plexiglas sheets, similarly heated, were then pressed between the reciprocal molds into that shape and allowed to cool. The Plexiglas pieces, which retain their shape when cooled, were then trimmed and polished, fitted with other pieces representing the other surfaces and cemented together with methyl dichloride. The latter, a solvent for Plexiglas, was brushed on the opposing surfaces to be joined and then the whole firmly held in a vise for a few minutes until the solvent evaporated. The pieces of Plexiglas were thus firmly united into a model of a lobe. The lobes so assembled were then cemented together into a replica of the lung. Small blocks of Plexiglas preserved a narrow clear space between the lobes to identify the fissure. The whole was then mounted on a vertical stem made of a solid Plexiglas rod and placed on a round rubber base. The entire model can be easily lifted, turned and handled.

These steps were repeated for each model (12 in all) in order to show the various stages of collapse of each upper lobe and of the left lower lobe. Normal models for each lung were also made. Separate series of models were made to depict the mode of collapse of each upper lobe because the direction of shift of the collapsing lobe is different. Models of the right lower lobe were not made because the mechanism of collapse is essentially the same as that for the left lower lobe. Collapse of the middle lobe was not illustrated, since it is relatively simple to understand.

For the normal or over-expanded lobes, transparent Plexiglas was used. To represent the collapsed lobe, a white translucent Plexiglas was employed. When viewed from the front or side, one sees the *white* collapsed lobe through the *transparent* normal lobe; in the same manner the roentgen ray penetrates the normal lobe, but the collapsed lobe casts a white shadow on the film.

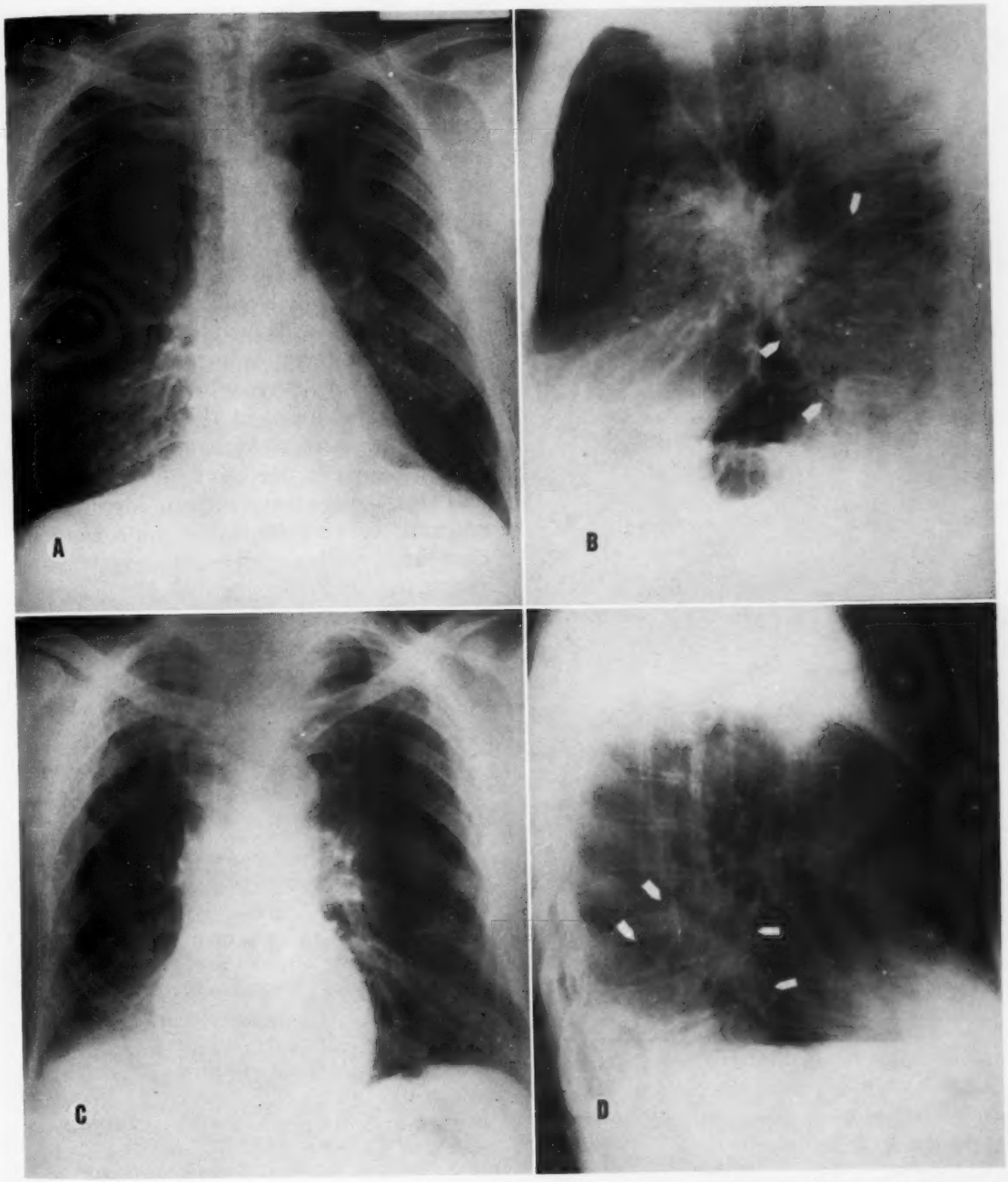


Fig. 9. *Advanced Stage—Collapse of Lower Lobe.* (*A*) Posteroanterior view. Collapsed left lower lobe flattened against mediastinum is seen as shadow of double density within heart border. Carcinoma. (*B*) Lateral view of *A*. Flattened collapsed lobe seen as faint triangle (arrows) in retrocardiac space. Compare with model. This represents entire lobe collapsed down to "mediastinal wedge." (*C*) Posteroanterior view. Collapse of right lower lobe. Haziness at right base. Postoperative collapse. (*D*) Lateral view of *C*. Collapsed lobe is flattened against posterior mediastinum (arrows). It is still in contact with most posterior part of right leaf of diaphragm. Note striking similarity to collapsed left lower lobe (*B*) and with model (Fig. 9*E*).

FIG. 9. (*E*) Model. Shown here as collapse of left lower lobe. Collapsed lobe seen through expanded upper lobe is now completely flattened against postero-inferior mediastinum, is roughly triangular in shape, and thin. This explains roentgen appearance of both posteroanterior and lateral views. Note similarity to complete upper lobe collapse, differing only in position of collapsed lobe. See models in Figures 4*C* and 7*C*.

We have used these models in teaching residents in radiology and in chest diseases, and it is our belief that they make it much easier to understand the underlying anatomico-spatial changes and the roentgen appearance of collapse.

These models were exhibited at the meeting of the American Roentgen Ray Society in Washington, D. C., in September of 1954. A few requests for sets of these models were received. However, the cost of reproduction of these models turned out to be too great (even with the master molds preserved) to make it practical for additional sets to be made. We attempted to fill many requests for photographs of the models. However, attempts to photograph these models were not satisfactory because of the transparency of the normal lobes and the numerous objectionable highlights created by the highly polished surfaces. It was impossible to preserve the three-dimensional effect we sought.

In order to preserve a record of these models, and to get wider distribution, we had perspective drawings of some of the models made by a medical illustrator; these drawings were then photographed and are reproduced in this report.

Together with the reproduction of each model, we have selected a posteroanterior and a lateral roentgenogram depicting a stage of lobar collapse of approximately that degree. By studying the pictures of the models serially, and then comparing them with the respective roentgenograms, one can gain a concept of the gross pathologic-anatomical and spatial changes that occur in lobar collapse far better than words can convey.

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We wish to express our deep appreciation to the Cuyahoga County Chapter of the American Cancer Society, which supported this work by a generous grant, and to the Rohm and Haas Corporation, which graciously supplied the Plexiglas. The clay models were made by us with the help and guidance of Mr. Walter Sinz, who supplied the finishing professional touches and made the plaster models. Mr. Donald Johnson and Mr. Peter Stevens executed the models in Plexiglas. The drawings were made by Mr. George Buckley. They were then photographed by Messrs. William Stevenson and Robert Newhouse of the Mount Sinai Hospital Department of Photography.

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Vol. 79, No. 2

A TECHNIQUE FOR BRONCHOGRAPHY

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THE usual methods of performing bronchography may be technically difficult, are apt to be uncomfortable for the patient and are frequently productive of inconsistent results. It has been our experience that preparation of the patient for tracheal intubation is slow, often difficult and may cause alarming symptoms of toxicity. Heublein and Gilfillan[1] have described the reactions to topical use of a 2 per cent pontocaine solution in bronchography as "fall in blood pressure, bradycardia, pallor, sweating, apprehension, tremor, dyspnoea, mild cyanosis and convulsive seizure." Miller and his associates[3] have experienced less severe toxic manifestation by using ½ per cent pontocaine in aerosol. Nevertheless the method is somewhat time consuming and requires special equipment. Whatever the method of introduction of opaque material into the trachea, its distribution throughout the bronchial tree depends upon gravity and positioning of the patient, except in the technically elaborate procedures utilizing positive pressure for injecting individual segments.

According to Shanks[4] opaque material

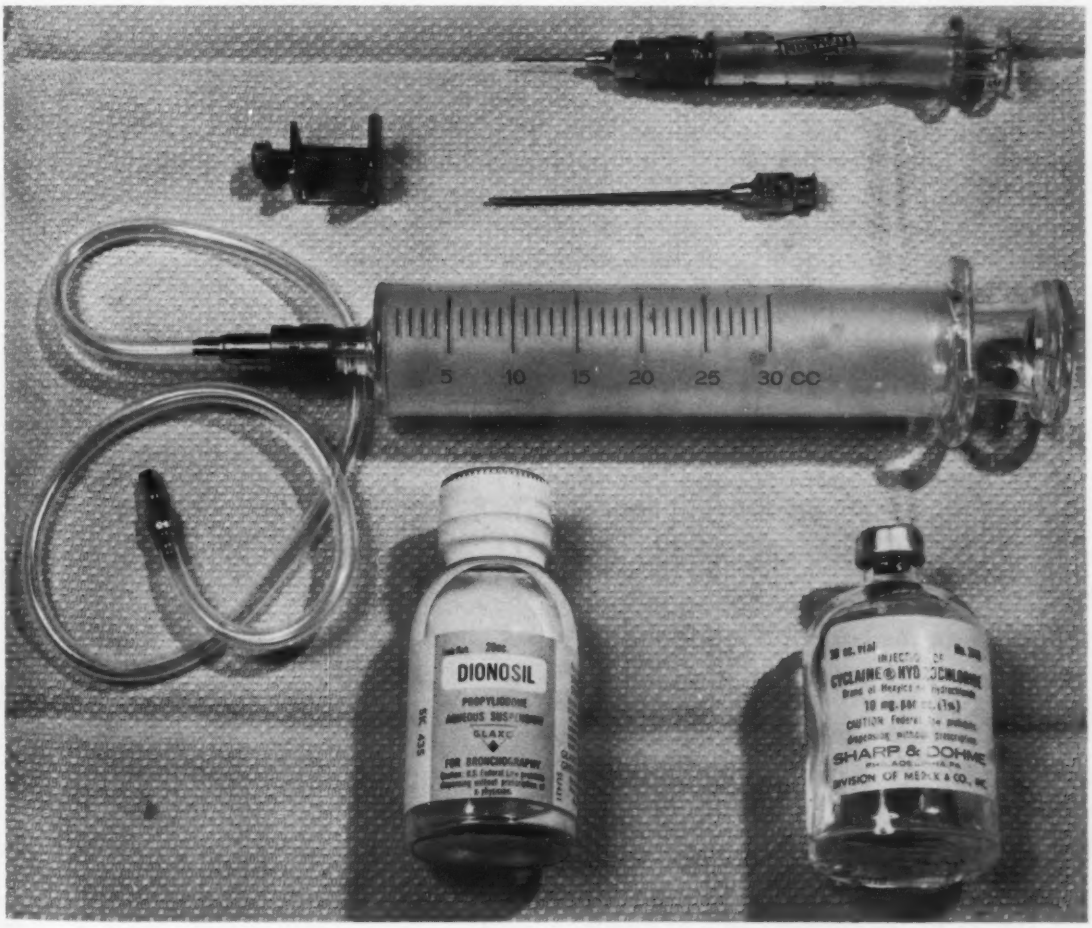

Fig. 1. Minimal equipment required for bronchography by transtracheal puncture.

FIG. 2. Lateral roentgenogram of the neck demonstrating the 16 gauge needle with guard which has been introduced into the trachea through the cricothyroid membrane.

was first introduced into the tracheobronchial tree by directly puncturing the trachea. There is the advantage of simplicity, minimal equipment (Fig. 1), and lack of embarrassing reaction to anesthesia. For several years this method has been used by us almost to the exclusion of other procedures. It is our impression that a similar technique has been used by other radiologists and by bronchoscopists and thoracic surgeons. Yet there seems to be a paucity of description in recent medical literature of any such technique, though there is no lack of description of methods employing tracheal intubation. Holden and Crone[2] are the authors of a paper concerning dionosil, the medium introduced by them directly into the trachea by puncture.

It has been our custom to give to an adult patient 25 mg. of probanthine and 1/32 grain of dilaudid hypodermically half an hour prior to the examination. Secretions are thus limited, apprehension allayed and cough reflex diminished. Similar effects may be obtained with other drugs. We do not ordinarily use barbiturates. It is important that the patient not be narcotized to a degree that will interfere with cooperation. The patient is placed upon a fluoroscopic table that can be tilted, the neck hyperextended over foam rubber positioning blocks so that the location of the cricothyroid membrane may be well determined. Local anesthesia is obtained by injecting 1 per cent cyclaine. The cricothyroid membrane is punctured with a 16 gauge needle to which a guard has been attached at such depth as to permit the needle to go into but not through the respiratory passage (Fig. 2). The guard is then strapped tightly to the neck with adhesive tape (Fig. 3), the needle tested as an airway, the head of the table elevated about 20 degrees and 1 per cent cyclaine injected slowly through the needle until cough is entirely suppressed. Ordinarily 4 cc. of solution is adequate, but on occasion, as much as 10 cc. has been used without evidence of toxicity. About a foot of flexible tubing is used to connect the needle with a 20 cc. syringe containing dionosil, which is slowly injected to complete filling of the tracheobronchial tree, or as much of it as is desired. At no time is the head of the table lowered to less than 20 degrees above horizontal, since flow of

FIG. 3. The patient is shown in position on the roentgenographic table with the neck hyperextended. The needle is strapped in place and connected to the syringe containing the opaque medium with flexible tubing.

the opaque material into the unanesthetized larynx will cause coughing. The upper lobes are readily filled with the patient in a lateral decubitus position, or in varying degrees of obliquity. Bronchial filling is accomplished and controlled under fluoroscopic observation. When the desired opacification is obtained the needle is removed and chest roentgenograms are made at a target-film distance of 6 feet.

A bronchogram by the method described is usually complete in ten minutes. The patient has not been distressed and the roentgenographic results are good. Originally we used lipiodol as a medium, but we greatly prefer aqueous or oily dionosil. With fluoroscopic control there should be no danger of infiltrating the soft tissues of the neck. Such an accident has occurred but without serious consequence. The method described is applicable to adolescents and older children.

SUMMARY

A technique for bronchography, employing cyclaine topical and local anesthesia, tracheal puncture, and dionosil opaque medium is presented. This or similar procedure is recommended for more wide spread usage because of minimal equipment requirement, simplicity, and freedom from reaction to an anesthetic agent.

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DUAL READING FOR CARDIOVASCULAR AND OTHER ABNORMALITIES ON ROUTINE 70 MM. PHOTOFLUOROGRAPHIC CHEST SURVEY*

By G. HOWARD GOWEN, M.D., F.A.C.P.,† *and* CLIFTON HALL, M.D.‡

PREVIOUS to 1945, chest photofluorographic surveys had been thought of principally in terms of pulmonary tuberculosis case finding. During the past ten years, however, there has been increasing interest in the potentiality of such surveys to detect other pathology, especially cardiovascular abnormalities and early bronchogenic carcinoma. It was the purpose of this study to assess the value and practicability of dual reading as a means to this end.

Experience has varied among different investigators as to the percentage of cardiovascular suspects among persons having routine chest photofluorograms. Dick,[7] Flancher,[9] Christie,[4] Pamplona,[20] Anderson,[1] Gowen[13] and Gowen and Frank[14] found the rate to be less than 1.0 per cent in community-wide surveys. In chest surveys of industrial workers, Flancher[9] found the cardiovascular suspect rate to be 1.0 per cent whereas Morse[19] reported less than 0.1 per cent in another industrial group. Hyman,[16] however, considered the prevalence of cardiovascular abnormalities on routine chest photofluorograms to vary from 2.0 to 6.0 per cent, depending on age and race. Schwartz and Berman[27] found a suspect cardiovascular abnormality rate of 4.5 per cent. In the case of hospital admission chest photofluorograms apparently the suspect rate runs higher, based on the reports of Scatchard and Duszynski,[26] and Batt *et al.*,[2] who reported respectively 16.0 per cent and 10.8 per cent.

With reference to preclinical detection of bronchogenic carcinoma through the use of community-wide chest photofluorographic surveys, Boucot and Sokoloff[3] reported an observed rate of 30 per 100,000 persons examined. Churchill's[5] case finding rate was 8 per 100,000, but when there was added the undetected cases which died of bronchogenic carcinoma within two years after the survey, the potential rate would have been between 16 and 20 per 100,000 persons examined. Scamman[25] reported a discovery rate of primary cancer of the lung of 7.8 per 100,000. Guiss[15] in a chest minifilm survey that included almost 2,000,000 persons found 11.8 cases of bronchogenic carcinoma per 100,000 examined.

Some interesting information has come forth in attempts to correlate photofluorographic findings with clinical findings in cardiovascular disease. Slattery[28] studied 682 persons who had satisfactory clinical investigation plus chest photofluorograms. Fifty-six had clinical evidence of heart disease, of which 25 (45.0 per cent) were detected on microfilm. Over half the rheumatic and hypertensive, and 43.0 per cent of the arteriosclerotic hearts were detected. Only 18.2 per cent of the cases of coronary heart disease showed enough alteration of the cardiac silhouettes to be detectable. Mart, Powers and Barth[18] compared 1,044 consecutive clinic patients studied photofluorographically with 1,044 who had photofluorograms only when specifically indicated. It was found that 5.5 per cent significant pathology was detected in the routine series as compared with 2.39 per cent in the selective group. Comstock found 739 (1.7 per cent) cardiovascular suspects among a group of 43,429 persons over fifteen years of age who had chest photofluorograms.[6] Three and one half years

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after the chest survey, he made a follow-up study and determined that in the surveyed population, about one fourth of the cardiovascular deaths in that period occurred among the photofluorographic suspects, although they made up less than 2 per cent of the group originally surveyed. The author felt that, using 70 mm. chest photofluorograms, it is possible from an abnormal appearance of the cardiovascular silhouette to select a group of persons whose risk of dying from renocardiovascular disease is much greater than of those not classed as having such an abnormality.

Intermingled with the many case finding studies, there has been a considerable amount of work done in an effort to evaluate and improve techniques. Garland and Cochrane[11] reported on a study of reader consistency by two groups of workers, one in Great Britain (six readers) and one in the United States (three readers). Eighty-nine 14 by 17 inch roentgenograms were studied that included cases showing signs of reinfection tuberculosis in the proportion of 5 to 30. Of 21 roentgenograms interpreted as tuberculosis positive unanimously by British readers, 20 were called positive unanimously by the Americans. There were 24 cases reported positive unanimously by the Americans. Disagreement was not unanimous by the British. In another study Garland[10] found, on all roentgenograms read, 16 per cent disagreement between individual readers and 8 per cent for the individual on re-reading. An editorial in *The Lancet*[8] in 1955 called attention to the fact that under test conditions readers of photofluorograms disagree with each other about 20 per cent of the time, and are little less consistent with themselves upon second reading. It was pointed out that the reason for this inconsistency is not apparent. It is not just a failure to detect slight changes because it is not only the minimal that is missed. Slattery[28] also emphasized this point when he observed that the detection of abnormal hearts coincides generally with the degree of enlargement, but in 7 undetected cases the hearts were more than 20 per cent oversize. To continue from the editorial in *The Lancet*, speed was not considered to be a factor although it does increase fatigue. Boredom and the hypnotic effect of repeated normals was thought important. It was suggested that opinion becomes biased in favor of the predominant, and after many more or less uniform photofluorograms, the reader may be less likely to remark on the slightly exceptional. It was stated that independent dual reading of 70 mm. photofluorograms was as effective as single reading of large roentgenograms. Stradling and Johnston[29] studied observer error in 70 mm. photofluorographic chest surveys for tuberculosis. They noted that two observers, independently reading a single posteroanterior photofluorogram achieved greater accuracy than either alone. Adding the anteroposterior lordotic view increased the yield for either reader, but not as much as the single view read by two observers. As would be expected, the best results were obtained by dual reading of both views. It was stated that the lordotic view decreased the number of recalls. Long and associates[17] reported on the chest photofluorograms of 20,973 men in the Armed Forces read routinely at their stations of origin, and independently by the roentgenologist of another station. There was a third reading by a referee of all photofluorograms in which abnormal findings were interpreted by either station. For photofluorograms definitely diagnosed as positive for tuberculosis, the original single reading yielded a rate of 40.53 cases per 10,000 films, dual reading of same films gave a rate of 61.98 per 10,000 with the same diagnosis, and cases added by each reader increased the discovery rate to 83.44 per 10,000 films. Dual reading of negativity reached between 98 and 99 per cent. It was stated that photofluorograms read as negative by two readers are more likely to be interpreted as negative in additional readings than if read as negative by only one roentgenologist. Batt *et al*[2] found no cardiovascular abnormalities using lateral photo-

fluorograms alone, but this view frequently served to confirm the posteroanterior findings. Rutstein *et al.*[24] noted that radiologists with special interest in cardiovascular disease will detect cases overlooked by chest physicians in community photofluorographic surveys. As was indicated previously, the cardiovascular suspect rate is higher in routine hospital admission chest photofluorograms than in community-wide surveys.[2,26] Golley[12] observed, during a routine chest photofluorographic survey for tuberculosis, that the hospital unit produced the highest per cent of positive cases, the health department unit the next highest, and the mobile unit the lowest per cent. This suggests that routine hospital admission photofluorograms should be quite productive, but only about 20 per cent of the general and special short-term hospitals in the United States have facilities for routine chest photofluorography.[23] Also, those that have such facilities do not use them to full capacity.

METHODS

This study is based on 23,741 routine 70 mm. photofluorograms taken in community-wide surveys in eight counties in Southern Illinois during the first six months of 1955. The usual chest reader read the photofluorograms, and did not know there would be a dual reading of the same films by a radiologist. The radiologist, however, knew the study was being made and that he was making a second reading of the films. In order to ensure that the chest reader was performing about as usual, a comparison was made between his findings in the surveys reported here and his findings when a similar, though not identical, population was examined two years earlier. This is shown in Table 1.

The chest reader noted a somewhat smaller percentage of photofluorograms positive on the current survey than on the previous survey. These differences appear to be negligible, however, in view of the fact that, if each survey had been read a second time by the chest reader, there might have been as much variation between the first and second reading of each survey as is evident between the single readings of the two surveys.

Each person showing suspect chest abnormality on single or multiple readings was so notified and advised to go to his family physician. The physician named by the person was sent a copy of the letter referred to above plus an interpretation of the photofluorographic findings and the reader's impressions. Accompanying the letter to the physician was a report form to be returned by him as soon as the diagnosis had been established. The categories listed were pulmonary tuberculosis, cancer, heart, and "other." Questions were asked whether the photofluorographic report (1) had brought to the physician's attention a condition in his patient not previously known, and (2) if this condition was amenable to treatment. These follow-up reports serve as the basis for tabulations of confirmed disease that form a part of this study. Follow-up reports not returned within four months were assigned to the local health department in that area for completion.

TABLE 1

COMPARISON BETWEEN 70 MM. PHOTOFLUOROGRAPHIC READINGS MADE BY CHEST READER ON CURRENT SURVEY AND PREVIOUS SURVEY*

Film Reading	Current Survey		Previous Survey	
	No.	Per Cent	No.	Per Cent
Total	23,741	100.0	22,848	100.0
Negative	22,845	96.2	21,839	95.6
Positive	896	3.8	1,009	4.4
Tuberculosis	391	1.6	392	1.7
Cardiac	161†	0.7	173	0.8
Other	46	0.2	63	0.3
Diagnosis Reserved	300	1.3	381	1.7

* The age, race and sex distribution of the two surveys did not differ more than 1 per cent.

† Includes 2 cases read positive for both cardiac and some other condition.

RESULTS

Table II shows the percentages of the total 23,741 photofluorograms read in the current survey which were considered positive for some abnormality by either the chest reader or radiologist. As shown, 92.6 per cent of the films were considered negative by both readers. The chest reader called 3.8 per cent positive while the radiologist called 6.0 per cent; 1.4 per cent of the films were considered positive only by the chest reader, whereas 3.6 per cent were considered positive only by the radiologist. Two and four tenths per cent were considered positive by both readers.

TABLE II

PERCENTAGE OF 70 MM. PHOTOFLUOROGRAMS CALLED POSITIVE FOR SOME ABNORMALITY BY CHEST READER COMPARED TO THOSE CALLED POSITIVE BY RADIOLOGIST

Chest Reader	Radiologist		
	Total	Negative	Positive
Total	100.0	94.0	6.0
Negative	96.2	92.6	3.6
Positive	3.8	1.4	2.4

All photofluorograms considered positive by either reader were referred for a diagnosis. The results are shown in Table III for each of three groups of referals. It is of particular interest that of the diagnoses received, the percentage confirmation was highest for films considered positive only by the radiologist. In general, where a diagnosis was received, the radiologist's findings tended to be confirmed somewhat more frequently than the chest reader's findings.

The kinds of disease diagnosed in each of these three groups are shown in Table IV. The chest reader and the radiologist missed tuberculosis to about the same extent. There was a marked discrepancy for heart disease, however, with the chest reader missing a total of 213 cases as compared with only 32 missed by the radiologist. The reason for this is shown in Table V where it can be seen that the chest reader considered only heart enlargement as reason for follow-up, whereas, the radiologist considered abnormalities in configuration and of the great vessels in addition to enlargement. Moreover, the radiologist noted enlargement considerably more frequently than did the chest reader which, combined with the additional types of abnormalities noted, gave him a yield of confirmed heart disease over three times as great as that obtained by the chest reader.

The question of whether a second reading of survey photofluorograms by a radiologist is justifiable is partly answered in Table VI. Here is shown the incidence of confirmed disease added by a second reading of the photofluorograms, *i.e.*, the numbers of persons with disease who would have been sent a negative report had a second reading not been made. As was pointed out above, the greatest contribution made by the radiologist was in the identification of heart disease.

TABLE III

DIAGNOSES RECEIVED AND DISEASE CONFIRMED FOR THREE GROUPS OF 70 MM. PHOTOFLUOROGRAMS

Diagnoses	No.	Per Cent	Per Cent
	Photofluorograms Positive by Chest Reader Only		
Total Positive	316	100.0	
No Diagnoses Received	139	44.0	
Diagnoses Received	177	56.0	100.0
No Disease	84	(26.6)	47.5
Disease	93	(29.4)	52.5
	Photofluorograms Positive by Both Readers		
Total Positive	580	100.0	
No Diagnoses Received	209	36.0	
Diagnoses Received	371	64.0	100.0
No Disease	154	(26.6)	41.5
Disease	217	(37.4)	58.5
	Photofluorograms Positive by Radiologist Only		
Total Positive	853	100.0	
No Diagnoses Received	356	41.7	
Diagnoses Received	497	58.3	100.0
No Disease	192	(22.5)	38.6
Disease	305	(35.8)	61.4

TABLE IV

DISEASES DIAGNOSED IN EACH OF THE THREE GROUPS SHOWN IN TABLE III

Confirmed Diseases	No.	Per Cent
	Photofluorograms Positive by Chest Reader Only	
Total Cases*	94	100.0
Tuberculosis	22	23.4
Heart Disease	32	34.0
Tumor	3	3.2
Other Chest Diseases	37	39.4
	Photofluorograms Positive by Both Readers	
Total Cases*	221	100.0
Tuberculosis	82	37.1
Heart Disease	102	46.2
Tumor	8	3.6
Other Chest Diseases	29	13.1
	Photofluorograms Positive by Radiologist Only	
Total Cases*	309	100.0
Tuberculosis	23	7.5
Heart Disease	213	68.9
Tumor	8	2.6
Other Chest Diseases	65	21.0

* Some individuals were counted more than once if more than one condition was diagnosed.

TABLE VI

CONFIRMED DISEASES FOUND BY CHEST READER AND ADDED BY RADIOLOGIST

Confirmed Diseases	Found by Chest Reader	Added by Radiologist	Total Found
Tuberculosis	104	23	127
Minimal	21	5	26
Moderately Advanced	16	1	17
Far Advanced	7	2	9
Stage Not Given	60	15	75
Heart Disease	134	213	347
Neoplasm	11	8	19
Other Diseases	66	65	131

DISCUSSION

In this study, dual reading of 70 mm. routine chest photofluorograms substantially increased the number of abnormalities detected. For tuberculosis case finding, the second reading could probably be done by another chest reader since, as shown in Table IV, the radiologist missed about as much confirmed tuberculosis as the chest reader, or was able to discover about the same amount of tuberculosis as the chest

TABLE V

CARDIOVASCULAR ABNORMALITIES NOTED ON 70 MM. PHOTOFLUOROGRAMS BY CHEST READER COMPARED WITH THOSE NOTED BY RADIOLOGIST SHOWING NUMBER OF POSITIVE DIAGNOSES RECEIVED, AND NUMBER AND PERCENTAGE OF THOSE CONFIRMED FOR WHICH A DIAGNOSIS OF HEART DISEASE WAS RECEIVED

Cardiovascular Abnormalities	No. Positive	Diagnoses Received	Heart Disease Confirmed	
			No.	Per Cent
	Noted by Chest Reader			
Enlargement	160	100	87	87.0
Abnormal Configuration	0	0	—	—
Heart Displacement	1	1	1	—*
Abnormalities of Great Vessels, etc.	0	0	—	—
	Noted by Radiologist			
Enlargement	438	257	241	93.8
Abnormal Configuration	12	7	4	57.1
Heart Displacement	2	1	0	—*
Abnormalities of Great Vessels, etc.	78	46	40	87.0

* Frequency too small for valid estimate of proportion.

reader. From the standpoint of discovering chest disease other than tuberculosis, however, the radiologist had a very definite advantage.

In addition to case finding it is important to know what benefits accrue to persons found with disease on chest photofluorographic surveys. The benefits to an early case of pulmonary tuberculosis or lung cancer are quite apparent, but for cardiovascular abnormalities the same cannot be said. First there is the question whether enough previously unknown cases are discovered to make the procedure worthwhile. As far as the cardiovascular field is concerned, reports would indicate that such surveys are productive enough in terms of identification of abnormality *per se*.[13,14,21,22,24]

The second and important question, however, is whether enough of the persons with previously unknown cardiovascular abnormality are in need of medical care and would be benefitted by medical care. This phase of the problem needs more thorough study, preferably under controlled conditions. We have made repeated efforts to obtain such information as part of the confirmatory diagnosis follow-up report used in the community-wide 70 mm. chest photofluorographic surveys, but feel that the replies are too incomplete and inaccurate to form the basis for any valid conclusions. For example, of the total of 751 abnormal findings reported to physicians, return diagnostic reports were received in only 378 instances (50 per cent). With regard to the question "was the condition previously unknown to you," in 180 instances there was no answer, and among the remaining 198 replies 56 (28 per cent) indicated that the reported condition was previously unknown.

In closing, the intent of the study was to attempt to evaluate dual reading, not the relative skills and training of the two disciplines involved (chest reader and radiologist). It was by chance that the two available technical consultants fell into those two categories. It is true that the radiologist knew the study was being made and the chest reader did not. The radiologist, however, was not asked to pay more attention to the identification of cardiovascular abnormality than any other condition. As a matter of fact, the original intent was to attempt to detect more early cases of lung cancer than were being found by one reading. There were no hard-and-fast deadlines for either the chest reader or the radiologist. In both instances the readings were done during their spare time. Therefore, one should not have been under any more pressure than the other. It is quite apparent that different levels of reading were used with particular reference to cardiovascular abnormality.

SUMMARY

1. A dual reading was made of approximately 24,000 70 mm. routine chest photofluorograms.

2. A chest reader was used for the first reading, and a radiologist for the second reading.

3. The second reading by the radiologist added substantially to the confirmed chest pathology found by the chest reader, especially cardiovascular abnormalities.

4. A thorough study is needed to determine as accurately as possible the benefits that accrue to persons found on chest photofluorographic surveys with cardiovascular disease, particularly since it far exceeds any other specific category.

5. There should be training and reorientation of chest readers with regard to pathology other than tuberculosis in order to increase the yield of such cases.

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ROENTGEN STUDIES OF VENTILATORY DYSFUNCTION: AN ANALYSIS OF DIAPHRAGMATIC MOVEMENT IN OBSTRUCTIVE EMPHYSEMA*

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MANY tests have been devised for evaluating the various factors in pulmonary function. The need remains for a relatively simple, widely applicable screening procedure which will readily detect and permanently record gross evidence of ventilatory dysfunction in an objective manner.

The maneuver which demonstrates evidence of gross ventilatory dysfunction most consistently is observation of the speed and amount of pulmonary emptying during a forced rapid expiration from the position of full inspiration. Devices for evaluating this function include the pneumotachograph, spirometer, and fluoroscope. The spirometer will record ventilation with requisite accuracy, but in its simple form will not differentiate between the ventilation of right and left lungs. A pneumotachograph has the same shortcoming. Spirometry, in its more complicated form of differential broncho-spirometry, furnishes differential function as well as a permanent record; but it requires the services of a pulmonary physiologist, an anesthetist, one or more laboratory technicians, and expensive laboratory apparatus with which few hospitals are equipped. Not only is there inconvenience to the staff; but intubation is highly uncomfortable for the patient. Fluoroscopy provides instantaneous observation of the motion of the diaphragm (which is related to ventilation) and fluoroscopic equipment is readily available at most hospitals. However, this method is highly subjective; interpretation of observations depends upon the training and skill of the fluoroscopist, and no permanent record is provided. Roentgen kymography of the diaphragm has been applied for many years in the study of respiratory disorders.[1,3,4,6,7,8,9,10,11,12,13,14]

We have modified the conventional techniques in applying the method of roentgen kymography of the diaphragm to the *quantitative* study of relationships between *differential pulmonary ventilation* and *the amount and speed of diaphragmatic rise during forced rapid expiration*. To the best of our knowledge, no investigator has previously utilized this method for quantitative evaluation of the ventilatory ability of each lung. Furthermore, those workers who have studied diaphragm motion with roentgen kymography have usually failed to apply those respiratory maneuvers which would adequately demonstrate a given respiratory disorder.[3,4,9,10,11,12,13,14]

Our attention has been particularly directed towards evaluation of function in patients with obstructive pulmonary emphysema. Epstein[3] has recently applied roentgen kymography of the diaphragm in a study of several types of chest disease, including obstructive emphysema. His study of 10 patients having the latter disease revealed normal wave forms of diaphragm motion during quiet breathing. However, *the basic physiologic defect in obstructive emphysema is not inability to ventilate during quiet breathing, but is, instead, the lack of ability to exhale a large volume of air rapidly*, usually due to

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generalized alveolar or bronchial airway obstruction. This is easily demonstrable if one observes a forced rapid expiration by any of several methods, *but is rarely evident if only quiet breathing is studied.*[2]

In this paper we present observations and data obtained from roentgen kymograms of the diaphragm taken during various respiratory maneuvers and attempt to bring out the correlation with pulmonary function tests and clinical observations. A special kymograph grid is utilized and is described below.

MATERIALS

For the present study, roentgen kymograms of the diaphragm were made by means of a conventional roentgen kymograph apparatus which contained a specially constructed grid. Lead strips in this grid were made 30 mm. wide and were spaced 1.0 mm. apart, the purpose being to permit recording of events during a four second time interval over a strip of film measuring 30 mm. in width. After considerable experimentation, the above dimensions were found optimal for obtaining a maximum number of scanning points while simultaneously spreading out a single diaphragmatic excursion wave so that its amplitude and rate of rise could be measured with requisite accuracy. The factor which influenced the selection of exposure time was the ability of normal patients to exhale within three seconds. Roentgen exposure factors were set as follows: 72 inches target-film distance; 1/16 inch aluminum filter; half-value layer of 2.60 mm. Al; 85 kv.; 100 ma.; 4 seconds exposure time. The grid was oriented with its strips in a vertical position and was fixed rigidly in place. Movement of the film occurred at right angles to the strips and from left to right (relative to the patient as he faced the film). With this technique, a record of motion of three 1 mm. segments of each diaphragm leaf is usually obtained on one 14×17 inch film. As a means of measuring time, a motor-driven timer with a rotating vane was mounted directly on the kymograph machine so that simultaneous time-marks were recorded every fifth of a second on the film during the exposure.

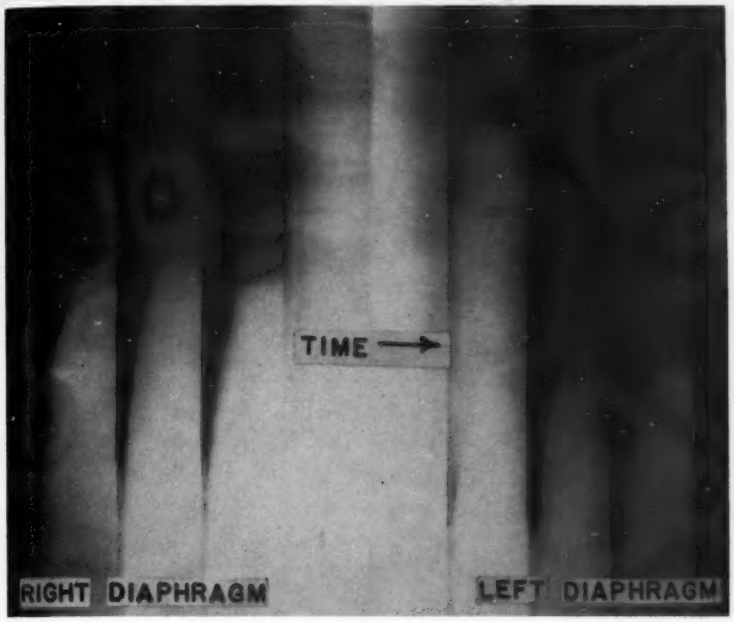
METHOD

For studying the presence of emphysema and certain other abnormalities, the patient was coached prior to each film exposure on the performance of maximum forced expiration from a position of maximum inspiration. While he was in inspiratory position, roentgen exposure was started so as to obtain a short segment of diaphragm baseline position on the film over about 1 second of time. Instruction was then given to the patient to perform a single forced expiration with maximum effort throughout the remainder of the exposure period. The film was then developed using routine technique and materials as for any roentgenographic examination.

MEASUREMENT

Each record usually contains at least three single wave crests for each leaf of the diaphragm, as seen in Figure 1*a*. The tallest wave of each side is compared with the other in Figure 1*b*. For convenience in measuring and interpreting waves, the film is placed on a viewbox with the patient's left side on the observer's right. Orientation of the curves is thus effected so that time increases from left to right. Each wave represents the motion of a 1 mm. segment of the diaphragm shadow plotted against time.

The origin or starting point of each wave is usually found with ease, since there is a sudden steep rise from the inspiration base-line. Simultaneous with this rise, the ribs will descend. The sudden dip of the ribs is plainly evident. A line drawn vertically through the rib shadow at the point of dip will therefore intersect the base-line at the exact origin of the diaphragm wave, a fact which helps to locate the wave—origin in those few cases in which the latter is not sharply delineated. Unsharpness at this point is usually due to the presence of a band of relative radiolucency beneath the level of the diaphragm throughout that portion of the exposure which precedes the



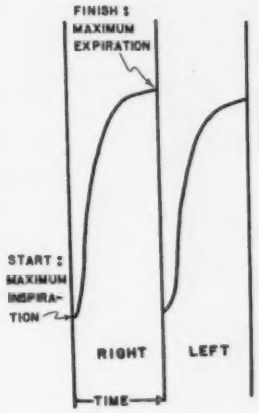
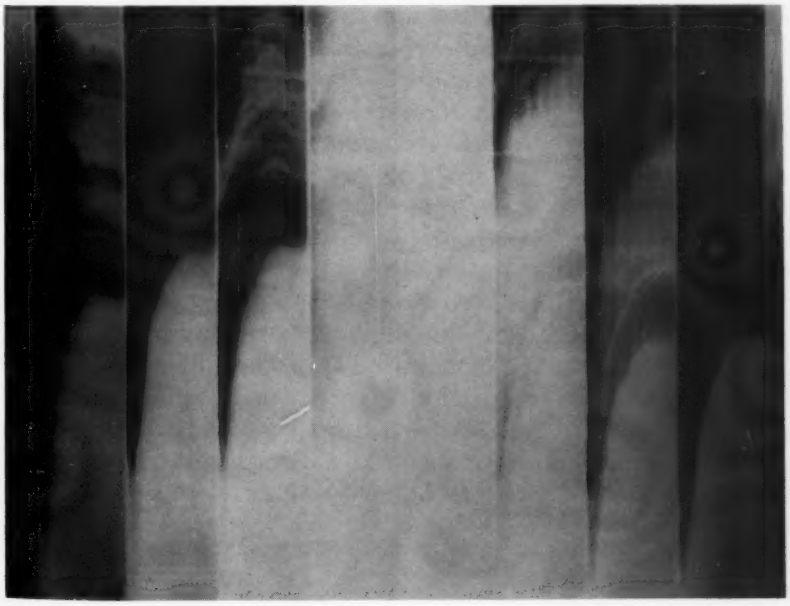


FIG. 1*a*. (left) The normal roentgen kymogram of the diaphragm taken during a single forced maximum expiration from a starting position of maximum inspiration. Time increases from left to right. The rise of both leaves is very rapid during the first second and achieves 89 per cent of its maximum height within this time interval.

FIG. 1*b*. (right) A line drawing of Figure 1*a*, showing the highest single wave from the right diaphragm leaf compared with the highest wave of the left diaphragm leaf.



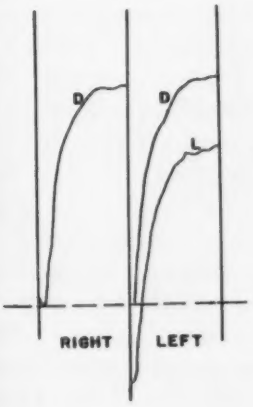
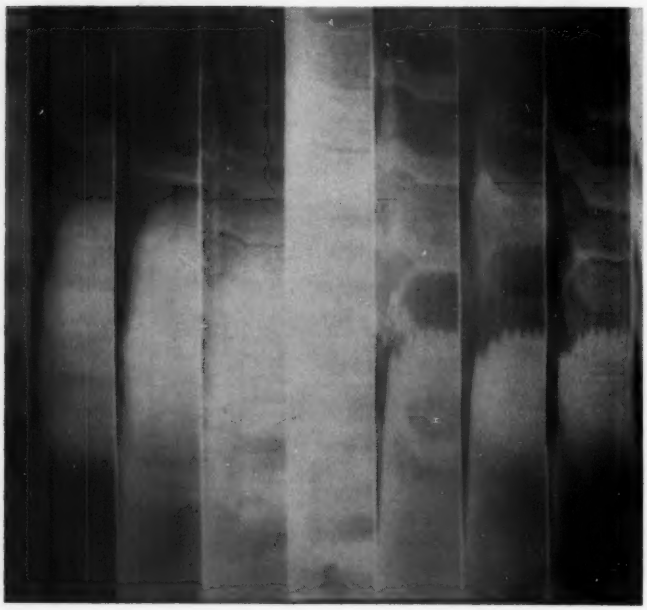


FIG. 2*a*. (left) A double tracing on the left side due to a gas-fluid level in the stomach.

FIG. 2*b*. (right) A line drawing of Figure 2*a*. The superior wave, D, is traced by diaphragm, while the inferior dense wave, L, records the motion of a 1 mm. segment of the fluid surface. The two amplitudes of rise are virtually identical.



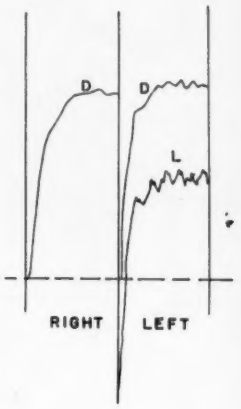


FIG. 3*a*. (left) Small notches in the trace of the left leaf produced by cardiac pulsations transmitted to the diaphragm.
FIG. 3*b*. (right) A line drawing of waves from Figure 3*a*. Diaphragm tracing: D. Fluid level tracing: L.

expiratory phase. We have interpreted as the source of the radiolucency, the presence of a lappet of inflated lung in the costophrenic sulcus. At the instant of diaphragm contracture, lung tissue in this region is suddenly compressed and deflated, thus furnishing a record of density beneath the diaphragm for the remainder of the examination.

Figure 4 demonstrates the method of measurement applied to the wave of each side which has the greatest amplitude of rise. (Usually, the middle wave of the three on each side is used, since it normally will have the greatest maximum amplitude.) A base-line is established by drawing a fine transverse pencil line through the origin or starting point (A) of a given wave and perpendicular to the vertical edges (V) of the film strips. The length of film travel which is equivalent to one second of time is then measured from the timing marker. This length is laid off on the drawn base-line, from the wave origin at point A in the direction of increasing time. The end of the first second is, therefore, indicated at point F on the base-line. A straight line is then drawn through F, perpendicular to the baseline, and intersecting the wave-curve at point R. The length of the line segment F-R is then recorded as a measure of diaphragmatic rise at the end of one second of forced expiration. Another line is drawn parallel to the base-line and tangent to the maximum rise of the wave. Measurement of the perpendicular distance M-X, between this line and the base-line is then recorded as the maximum diaphragmatic excursion. Ventilation partition or differential lung ventilation is related to the rise of each diaphragm. Therefore, we establish a kymographic determination of the percentage ventilation performed by each lung as follows: The ratio of the maximum excursion of one side to the sum of the maximum excursions of both sides, multiplied by 100, is called the percentage ventilation of the given lung.

THE NORMAL EXPIRATORY ROENTGEN KYMOGRAM

Twenty normals, ranging in age from eighteen to fifty-five, were tested with this technique. Maximum diaphragm excursion ranged from 4.8 cm. to 8.6 cm. with an average maximum excursion value of 6.6

cm. for the right diaphragm leaf and 7.7 cm. for the left. However, 90 per cent of normals fall within 4 mm. of the average value, and therefore, this figure is used as a baseline. About half of the cases had greater excursion on the right; the remaining half had greater excursion on the left. Few instances of exactly equal amplitudes were encountered among the normals. However, little significance can be attached to lack of equality, since maximum measurement error was estimated at about ±3 mm., and the difference between right and left sides in some patients was as little as 1 mm.

In all of the normals tested, rate of rise was relatively rapid. Slopes of normal waves were therefore very steep. The average normal rate indicated a diaphragmatic rise of 89 per cent of the maximum excursion of the diaphragm within the first second. It is of considerable interest to compare this result with vital capacity figures which show that a normal individual can exhale 83 per cent of his vital capacity during the first second.

Following the first second of time, the wave form usually assumed a sharply rounded contour which continued throughout the next second. A plateau was then reached just prior to, or immediately following, the beginning of the third second. The plateau, or point of maximum excursion represents the end position of the diaphragm segment and is usually of constant amplitude above the time axis. Thus, by the end of the third second, most normals exhaled completely. Some continued to rise at a very slow rate after this time, probably as a result of not applying maximum effort throughout the third second.

One effect which is noted in normals, as well as in abnormals, is the appearance of a double wave in the record of the left diaphragm leaf, one wave appearing above the other. This is due to the presence of gas in the fundus of the stomach. The diaphragm itself makes the uppermost wave, while the motion of the fluid level beneath stomach gas forms the inferior curve. Since the two waves are always clearly separable and synchronous, their occurrence usually offers no problem in measurement. In data recorded so far, the two waves are so similar in amplitude and slope as to make feasible the measurements described above applied to the *inferior* wave in those instances when pleural thickening obscured the superior wave. Figure 2*a* and 2*b* show the double wave on the left side.

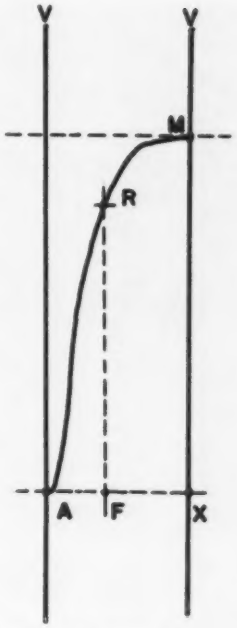
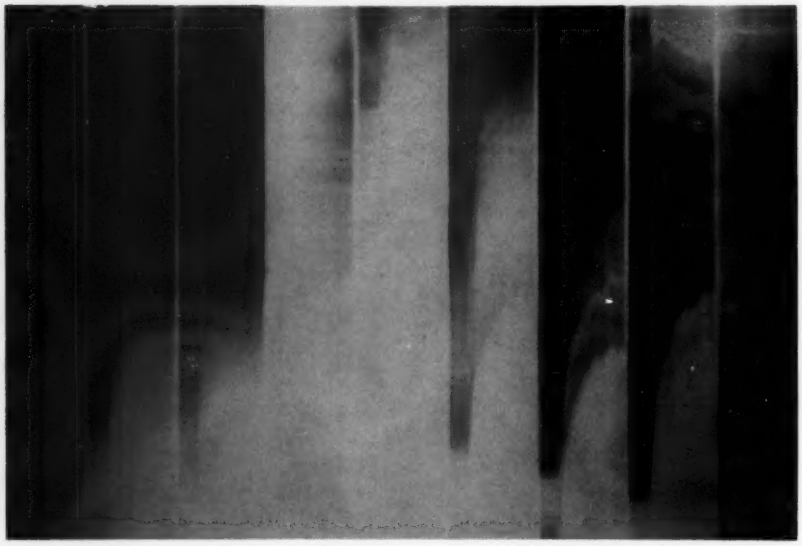


Fig. 4. The method of wave measurement. V is the vertical edge of each film strip. Point A is the starting point (usually from a position of full inspiration) of the scanned diaphragm segment. A baseline is drawn through A, perpendicular to vertical edges, V. From timing marks, the first second is measured to the right from point A and is indicated by point F. A line is erected perpendicular to F and intersecting the wave trace at R. Then the line segment, F–R, measured in cm., is the height of rise during the first second and is used as a measure of the *speed* of rise. The distance from the baseline to the highest point of the curve, M, is the *amplitude* or *total height* of rise.

Another feature of the curves appears frequently, *viz.*, notching of the wave in a uniformly periodic form by secondary or modulating waves of very small amplitude. These are caused by cardiac pulsations transmitted to the diaphragm; they do not interfere seriously with measurement or qualitative evaluation. Figures 3*a* and 3*b* demonstrate the effect of the heart beat on the wave form.



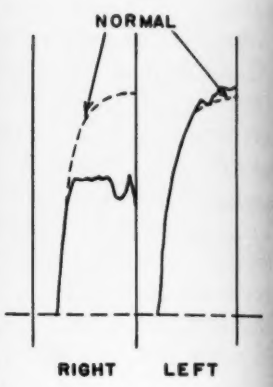


FIG. 5*a*. (left) Case I. The roentgen kymogram of a patient having unilateral ventilation deficiency due to tuberculosis and obstructive emphysema.

FIG. 5*b*. (right) A line drawing of Figure 5*a*. The wave having the greatest amplitude on the right side is compared with the tallest wave on the left. A normal tracing is indicated by the broken line. The left leaf has a normal excursion and rate of rise. Right-sided excursion is markedly reduced in amplitude and the rate of rise is sharply reduced at the end of about 0.5 seconds. Interpretation: Unilateral obstructive emphysema and loss of lung parenchyma with the involved lung performing only 38 per cent of total ventilation. (See text.)

THE ABNORMAL EXPIRATORY ROENTGEN KYMOGRAM

REPORT OF CASES

To date, 47 patients with ventilatory dysfunction have been tested by this method.

CASE I. The first abnormal roentgen kymogram is the record of a patient with predominantly right-sided pulmonary tuberculosis and obstructive emphysema and is demonstrated in Figure 5*a* and 5*b*. Pulmonary function tests revealed the following data: Vital capacity (V.C.) = 2.9 liters; maximum breathing capacity (M.B.C.) = 75 liters per minute; differential bronchospirometry ventilation: right: 26 per cent; left: 74 per cent. The latter figures are a measure of ventilation partition, that is, the percentage of ventilation performed by each lung.

The roentgen kymogram shows a normal amplitude of rise and speed or rate of rise of the left diaphragm leaf, while the right leaf has marked reduction in maximum amplitude and rate of rise after 0.5 seconds. By actual measurement, the left hemidiaphragm rose steeply to a height of 5.7 cm. in the first second (the speed or rate of rise during the first second); it reached a maximum excursion of 7.2 cm. at the end of the exposure period. These figures are well within the normal range of values. However, the right hemidiaphragm rises only 4.0 cm. during the first second and rose very little more when it had reached maximum excursion of 4.1 cm. The decrease in maximum excursion or amplitude of rise is interpreted as decreased *total amount* of pulmonary ventilation, whereas decreased *speed* of rise is interpreted as decreased *rate or speed* of ventilation. The percentage ventilation of the right lung determined by roentgen kymography is:

$$\frac{4.1 \text{ cm.}}{4.1 \text{ cm.} + 7.2 \text{ cm.}} \times 100 = 36 \text{ per cent.}$$

This may be compared with the data above obtained by bronchospirometry.

Our impression then obtained from the roentgen kymogram was that the patient has lost considerable functioning lung (relative to ventilation) and has obstructive emphysema on the right side while his left lung is ventilating normally. We would venture to predict from the roentgen kymogram alone that the right lung is performing less than 40 per cent of the total ventilation during forced expiration.

CASE II. The next roentgen kymogram shown

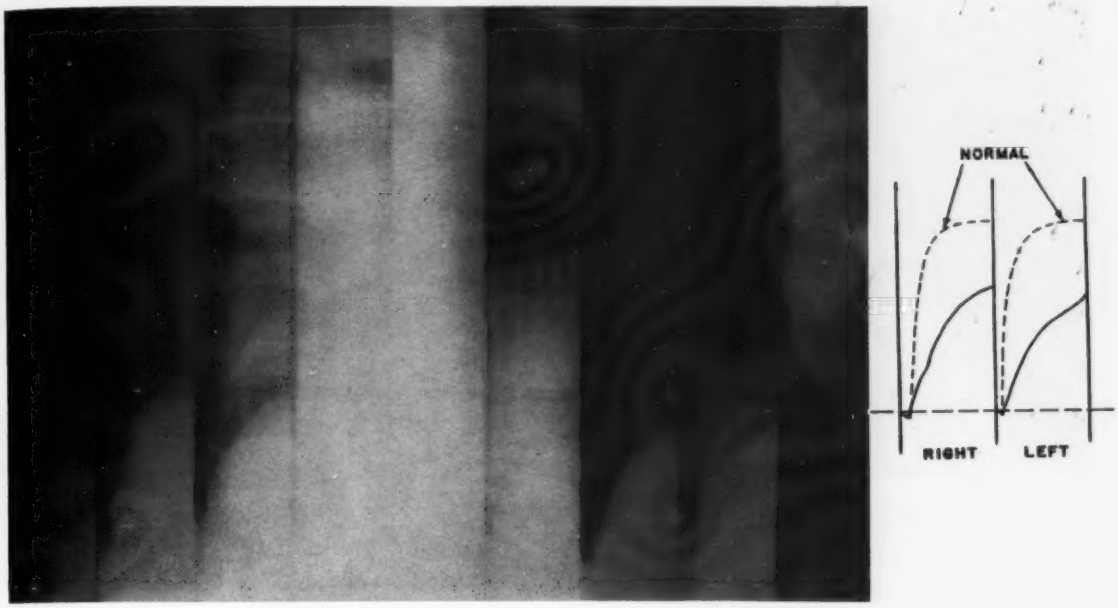


Fig. 6*a*. (left) Case II. Moderate bilateral ventilation deficiency due to pulmonary tuberculosis and obstructive emphysema with significant exercise intolerance. Moderate reduction in amplitude and rate of rise of about equal magnitude on both sides.

Fig. 6*b*. (right) A line drawing of Figure 6*a*, comparing the maximum excursion wave of both sides. Percentage ventilation is virtually equal by roentgen kymography. Confirmed by bronchospirometry. Interpretation: Bilateral loss of parenchyma and obstructive emphysema.

in Figure 6*a* is the record of a forty year old male who has pulmonary tuberculosis which has destroyed about half of each upper lobe. Clinically he has obstructive emphysema bilaterally but has no significant exercise intolerance. Pulmonary function tests revealed the following data: V.C. = 3.2 liters; M.B.C. = 83 liters/minute; differential bronchospirometry ventilation: left 43 per cent; right 57 per cent.

His roentgen kymogram shows a moderate reduction in amplitude and rate of rise on both sides with function on the right minimally different from that on the left. It is our impression that this type of record indicates loss of ventilating lung tissue (evidenced by decreased diaphragm excursion) and airway obstruction (as evident from decreased rate of rise). Furthermore, since the changes were about the same by measurement on both sides, we inferred that loss of ventilatory function was about equal on each side.

Case III. The roentgen kymogram of a sixty-four year old male with almost complete loss of one lobe on the left and partial loss of one lobe on the right due to tuberculosis is shown in Figure 7*a*. Clinically he demonstrated obstructive emphysema as well, and was dyspneic on mild exertion. Pulmonary function tests revealed the following: V.C. = 2.9 liters; M.B.C. = 59 liters/minute; differential bronchospirometry ventilation: left 24 per cent; right 76 per cent.

His roentgen kymogram demonstrates a moderately decreased amplitude and speed of rise on the right and a marked decrease on the left. From measurements of these waves it was predicted that only about 25 per cent of the patient's total ventilation was performed by the left lung during forced expiration. This is in close agreement with the figure of 24 per cent above obtained by bronchospirometry.

Case IV. Figure 8*a* is the record of a patient with severe obstructive emphysema and bilateral pulmonary tuberculosis. Pulmonary function tests gave: V.C. = 3.5 liters; M.B.C. = 27 liters/minute. Differential bronchospirometry was not performed in his case.

A roentgen kymogram, obtained during forced maximum expiration, demonstrates marked decrease in speed and a moderate decrease in amplitude of diaphragmatic excursion bilaterally, worse on the left. The curves were interpreted as indicating severe airway obstruction with associated loss of lung parenchyma

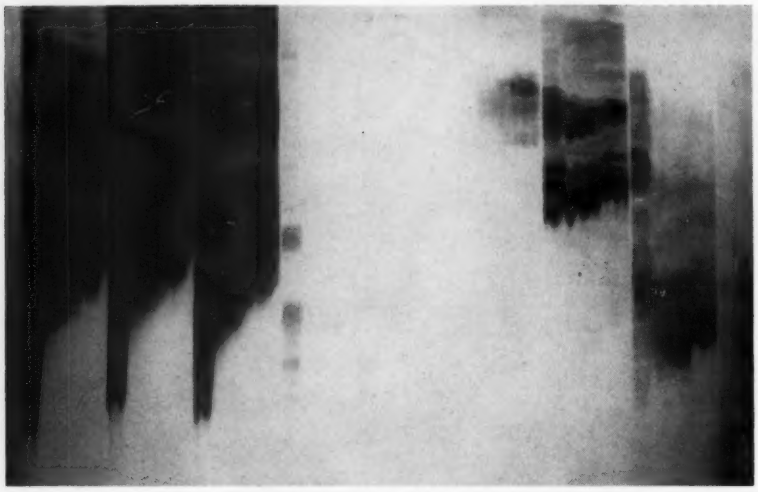
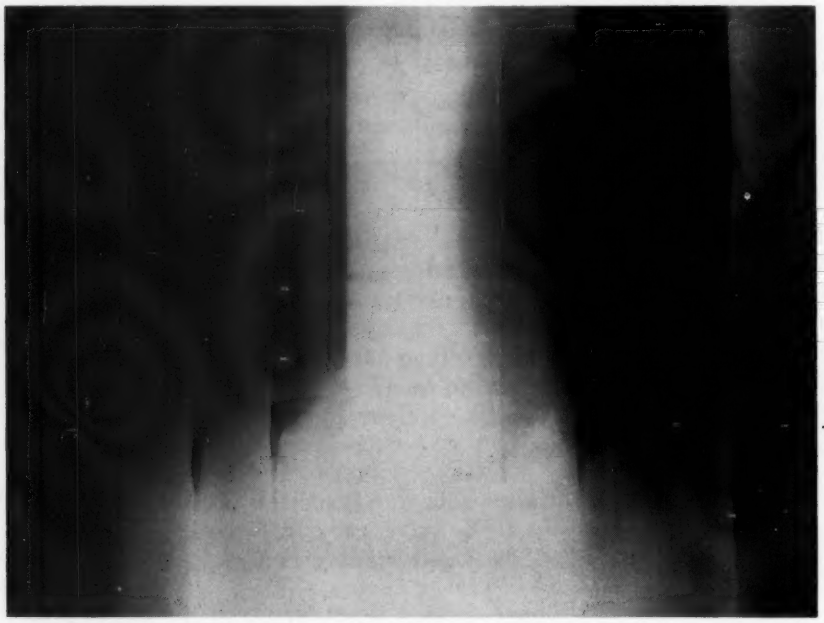


FIG. 7*a*. (left) Case III. Moderate ventilatory loss on the right side and severe loss on the left side due to tuberculosis and obstructive emphysema. Dyspnea on mild exertion.

FIG. 7*b*. (right) A line drawing of Figure 7*a*, comparing the maximum excursion wave of both sides. There is moderately decreased amplitude and speed of rise on the right side of the diaphragm and marked decrease in both factors on the left. From measurements of the waves it was predicted that a partition of 25 per cent ventilation existed on the left. Bronchospirometry showed 24 per cent ventilation on the left side. Interpretation: Bilateral obstructive emphysema, worse on the left, associated with moderate loss of ventilating parenchyma on the right and severe loss on the left.



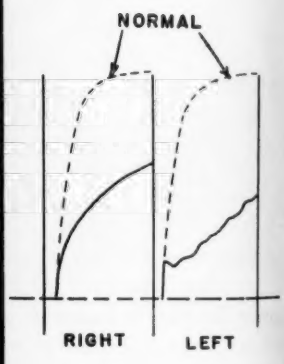
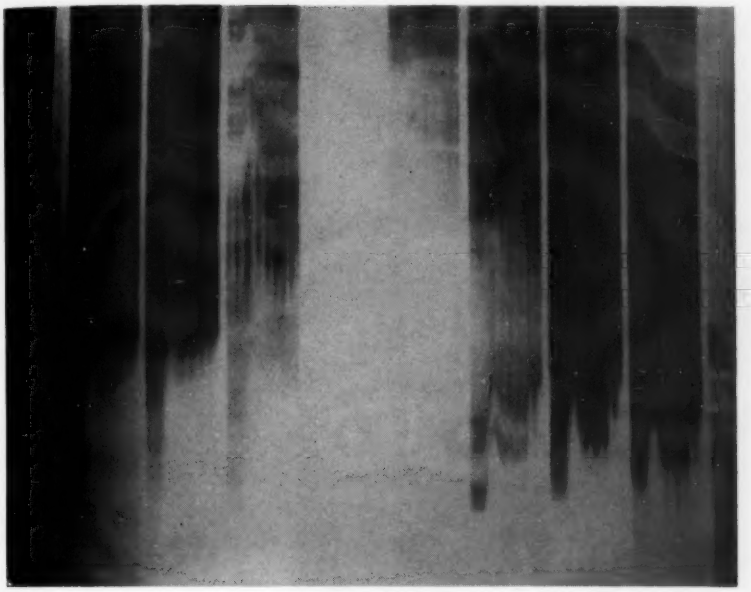


FIG. 8*a*. (left) Case IV. A patient with bilateral ventilatory dysfunction due to severe obstructive emphysema and bilateral pulmonary tuberculosis.

FIG. 8*b*. (right) A line drawing of Figure 8*a*, comparing the maximum excursion wave of both sides. There is marked decrease in speed and moderate decrease in amplitude bilaterally with the greatest changes being present on the left side. Interpretation: Bilateral loss of parenchyma and diffuse air-way obstruction, worse on the left.



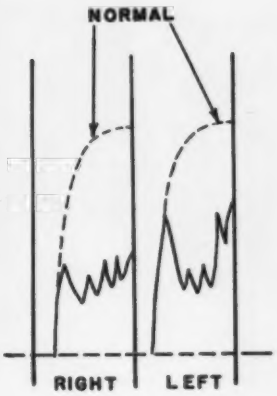


Fig. 9*a*. (left) Case v. The roentgen kymogram of a patient with generalized bullous emphysema, severe dyspnea on exertion, and markedly diminished values on pulmonary function tests.

Fig. 9*b*. (right) A line drawing of Figure 9*a*, comparing the maximum wave of both sides. There is great reduction in amplitude of rise, and the rate of rise is completely irregular with bilateral oscillations of each leaf, probably due to compression and recoil of bullae.

bilaterally; ventilatory dysfunction is greatest on the left.

Case v. Figure 9*a* is the roentgen kymogram of a sixty year old white male patient with widespread bilateral bullous emphysema, severe dyspnea on exertion, and markedly diminished values on pulmonary function tests which gave: V.C. = 1.9 liters; M.B.C. = 32 liters/minute.

During forced expiration, his roentgen kymogram demonstrates great reduction in amplitude of rise and the rate of rise is completely irregular with frequent oscillations of each leaf. Since the action of the diaphragm is a completely passive one during expiration, it was concluded that the diaphragm was bouncing against obstructed lung parenchyma which was alternately compressing and recoiling. Close observation during the examination showed that the patient was *exhaling only* throughout the test, so that diaphragm movements do not indicate rapid inspiration-expiration cycles.

Case vi. Figure 10*a* is the roentgen kymogram of a twenty-five year old male with marked destruction of the left lung and considerable destruction of the right lung due to tuberculosis. He has associated obstructive emphysema and has complete paralysis of the left diaphragm leaf. The pulmonary function tests gave: V.C. = 2.6 liters; M.B.C. = 87 liters /minute.

His roentgen kymogram, which was recorded during forced, single maximum expiration, reveals the presence of true paradoxical motion of the left leaf. Both sides are highly abnormal, however, with marked decrease in maximum amplitude and rate of rise of the right hemidiaphragm in addition to the left-sided changes already described. From these records alone it may safely be predicted that the patient's total ventilation is markedly reduced and that the left lung is producing only a very small fraction of this ventilation. In interpreting the roentgen kymogram, one must keep in mind that the record started when the patient was holding a maximum inspiration. His left hemidiaphragm moves paradoxically and, therefore, started from an abnormally high inspiratory position. Consequently it descends upon expiration while the normal right leaf rises.

Diaphragmatic Paralysis Associated with Obstructive Emphysema

Report of a Case

Certain deviations from the above method of testing during forced maximum

FIG. 10*a*. (left) Case VI. Diaphragmatic paralysis on the left side due to phrenicectomy and bilateral tuberculosis associated with pulmonary emphysema. There is true paradoxical motion of the left diaphragm leaf during forced expiration.

FIG. 10*b*. (right) A line drawing of Figure 10*a*, comparing the motion of right and left diaphragm leaves. Note that the right lung is also ventilating poorly with marked decrease in amplitude and rate of rise of the right hemidiaphragm, indicating loss of parenchyma and air-way obstruction.

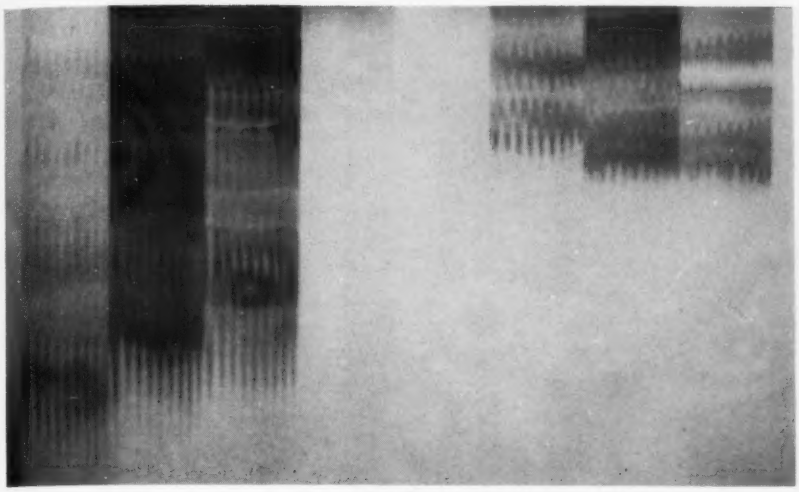
expiration have suggested themselves in special cases.

CASE VII. An application of these auxiliary methods is related in the following study of a forty-two year old white male patient who underwent surgical repair of a diaphragmatic hernia about two years ago. During the operation, the entire left hemidiaphragm was surgically divided as was the left phrenic nerve. His postoperative recovery was uneventful. However, on returning to work, he experienced exertional dyspnea out of proportion to what one would expect from phrenic paralysis alone. The clinical problems in this case were to evaluate diaphragmatic function and to determine the presence of generalized airway obstruction which might be a factor in his dyspnea.

Figure 11*a* demonstrates a roentgen kymogram taken during the performance of deep, rapid, inspiration-expiration cycles such as would be performed during a maximum breathing capacity exercise. In addition to the anticipated severe reduction in amplitude of the left hemidiaphragm, there is also a moderate reduction on the right side which was entirely unexpected and which for the first time pointed to the existence of pathology in the right chest. These abnormalities are readily apparent when the above tracing is compared with the tracing of a normal patient obtained during a maximum breathing capacity exercise, as shown in Figures 12*a* and 12*b*.

In the abnormal kymogram of Figure 11*a* careful measurements reveal the fact that excursion peaks of the right side exactly coincide in time with corresponding peaks on the left. Therefore, it may be concluded that *during rapid respiration cycles*, there is no paradox. However, the left lung is hardly being ventilated. Fluoroscopic observation during such an exercise confirmed this impression. The abnormality in right-sided amplitude on rapid breathing will be discussed later.

The most severe tests of diaphragmatic action occur during sudden changes of intrathoracic pressure which can be produced by the inspiratory "sniff" exercise. Figures 13*a* and 13*b* show what happened in the same patient when he was instructed to sniff sharply in the middle of quiet breathing exercises. Note the very sharp *dip* which occurs in the right diaphragm at this point. At exactly the same instant, the left leaf



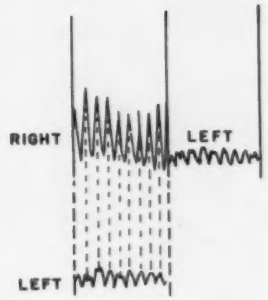


FIG. 11*a*. (left) Case VII. A patient with left diaphragmatic paralysis and bilateral obstructive emphysema. Rapid, deep inspiration-expiration cycles (Maximum breathing capacity exercise.)

FIG. 11*b*. (right) A line drawing comparing right and left sides in Figure 11*a*. The left tracing is also plotted synchronously with and underneath the record of the right side to show the coincidence of peaks in this exercise. There is moderate reduction in amplitude of excursions on the right side (compare with normal maximum breathing capacity tracing in Figure 12*a* and 12*b*), and severe reduction in amplitude of left leaf rise.

rises to a needle-peak. Therefore, movement of the leaves *is* paradoxical on sudden decrease in intrathoracic pressure.

Another question was raised by conflicting opinions relative to the physical examination of the patient. Some examiners thought they heard expiratory wheezes on auscultation while others did not. The possibility of superimposed obstructive emphysema was, therefore, to be evaluated. Towards this end, the roentgen kymogram of Figures 14*a* and 14*b* was obtained during a single forced maximum expiration. Notice that a notch appears during the last portion of expiration on the right. This is interpreted as indicating the presence of airway obstruction which was, in all probability, the

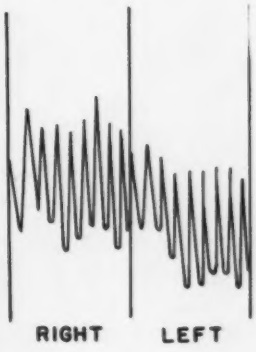


FIG. 12*a*. (left) A normal patient performing a maximum breathing capacity type of exercise. Note the amplitude of excursions.

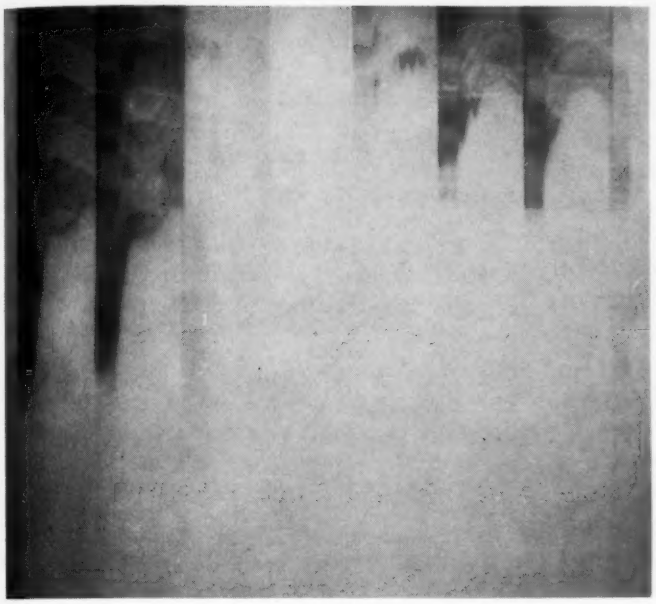
FIG. 12*b*. (right) A line drawing of Figure 12*a*, comparing the two normal sides.

FIG. 13*a*. (left) Case VII. Inspiratory "sniff" test. The left diaphragm trace rises in a sharp needle-peak while the right leaf descends very sharply at the same instant. (The sniff was performed during quiet breathing cycles.) Note that paradox occurs during the sudden change in intrathoracic pressure in this patient.
FIG. 13*b*. (right) A line drawing from the record of Figure 13*b* with the left diaphragm leaf plotted synchronously with the tracing of the right leaf.

cause of decreased right-sided amplitude during the rapid breathing test of Figure 11*a*.

On the left side the curve shows no evidence of paradox during single forced expiration. Note that the initial inspiratory position at the beginning of the record is abnormally high in Figure 14*a* as would be expected of a paralyzed diaphragm leaf. Both amplitude and rate of

FIG. 14*a*. (left) Case VII. Roentgen kymogram obtained during single forced maximum expiration. Notching of right tracing. Decreased amplitude and rate of rise on the left. Note that motion is *not* paradoxical in this exercise. Interpretation: Obstructive emphysema is present on the right side and may exist on the left, independently of diaphragm dysfunction.
FIG. 14*b*. (right) A line drawing from Figure 14*a*, comparing the motion of the two sides.



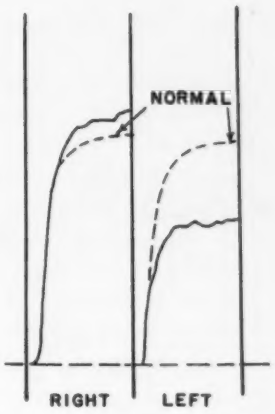


Fig. 15*a*. (left) Case VII. Expiratory roentgen kymogram taken after the administration of a bronchodilating agent (isuprel). Note improvement in amplitude on the right and in rate of rise on both sides. Interpretation: There is bilateral obstructive emphysema which is relieved to a significant degree by bronchodilating medication.

Fig. 15*b*. (right) A line drawing of Figure 15*a*, comparing the right and left sides.

rise are markedly decreased on this side.

The question naturally arises as to how much, if any, of the left-sided dysfunction might be due to airway obstruction in the left lung, superimposed on the diaphragmatic paralysis. To find an answer to this problem, a bronchodilating agent, isuprel, was administered prior to the patient's performance of a second single forced expiration test. Figure 15*a* is a roentgen kymogram recorded during the latter exercise. It demonstrates improvement in both amplitude and rate of rise on the right side (evidenced by disappearance of the notch) and improved rate of rise on the left side (Fig. 15*b*).

The findings were interpreted as indicating the presence of bilateral obstructive emphysema associated with left diaphragmatic paralysis. It was further suggested that the patient would be helped by maintenance doses of isuprel. This was tried with resultant decrease in exertional dyspnea, to the point where he was enabled to return to work. His pulmonary function studies taken before and after administration of isuprel are as follows: V.C. before isuprel = 3.04 liters, after isuprel = 3.22 liters; M.B.C. before isuprel = 70 liters/minute, after isuprel = 83 liters/minute; differential bronchospirometry ventilation before isuprel: left = 30 per cent, right = 70 per cent. (Compare with 40 per cent partition on left predicted by roentgen kymography.)

It is interesting to compare the motion of this patient's paralyzed diaphragm with that of Case VI (Fig. 10*a*). To account for the apparent discrepancy whereby paralyzed leaves in different patients move in opposite directions from one another during the same respiratory mode, one must consider the importance of mediastinal motion and mobility, fixation or loss of elasticity of pleura and lung parenchyma, the presence and degree of obstructive emphysema, and structural distortion of the diaphragm. All of these factors act in a complicated manner to influence the resultant diaphragm motion. One cannot, therefore, predict in advance the total intrathoracic dynamics solely from the information that the diaphragm is paralyzed on one side.

CONCLUSIONS AND SUMMARY

A need exists for a rapid, inexpensive and atraumatic screening method to detect ventilatory dysfunction. In particular, the

examining physician needs to know the degree of dysfunction in *each* lung as well as the *total* dysfunction. It is believed by the authors that when used under the proper testing conditions of certain respiratory exercises, roentgen kymography of the diaphragm furnishes such a quantitative method. Previous studies on diaphragmatic roentgen kymography have not attempted quantitative application of the method, and have failed to apply the proper respiratory exercises in the evaluation of a given pulmonary dysfunction. To lengthen record tracings for more accurate measurement, a special grid replaces the usual grid used in cardiac roentgen kymographs. Vertical motion of the diaphragm then serves as an indicator of *how much* ventilating lung parenchyma remains in each lung and of *how fast* each lung can perform the ventilation. We can, therefore, detect the presence of airway obstruction associated with emphysema or other cause in addition to the degree of lung destruction as indicated by our experience with 47 patients having these abnormalities.

Predictions of percentage ventilation of each lung by this method have excellent statistical correlations with pulmonary function tests. These correlations will be the subject of another publication. It is to be emphasized, however, that no single type of examination furnishes absolute delineation of a patient's pulmonary function. Correlations, therefore, between any two tests, are not as important as what a given test demonstrates. Roentgen kymography of the diaphragm is applicable as a screening method to demonstrate the presence of unilateral or bilateral obstructive emphysema and loss of ventilating lung parenchyma.

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PSEUDOPNEUMOPERITONEUM*

SIMULATED FREE AIR IN THE PERITONEAL CAVITY

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THE presence of free air in the peritoneal cavity, as a rule, offers no problem in the roentgenographic diagnosis when adequately exposed films are obtained. Occasionally, "spontaneous pneumoperitoneum" is not demonstrated on roentgenograms even though a definite perforation in the gastrointestinal tract has taken place as proved by surgery or autopsy. This lack of demonstrable air in the peritoneal cavity following a perforation of a hollow viscus occurs in approximately 25 to 35 per cent of cases.

Free gas in the peritoneal cavity is regarded as pathognomonic of a perforated hollow viscus in the absence of "diagnostic pneumoperitoneum," "therapeutic pneumoperitoneum," recent laparotomy or perforation of the abdominal wall. A few rare cases of "idiopathic pneumoperitoneum," or free air in the peritoneal cavity without demonstrable cause, have been reported.[1,2,3,4] These patients exhibited few, if any, symptoms although none that could be attributed to a perforated hollow viscus with peritonitis. Abdominal distention was present in some of these cases due to large amounts of gas in the peritoneal cavity, but there was no evidence of peritonitis either clinically or surgically. The presence of free gas in the peritoneal cavity was usually a coincidental finding. The etiology of free air in the peritoneal cavity in these cases is not clear. Many causes for this type of pneumoperitoneum have been postulated including microperforations of the bowel, pneumatosis cystoides intestinalis, entrance of air into the peritoneal cavity via the fallopian tubes, and in one case a communication between the lung and peritoneal cavity through a diaphragmatic hiatus was suspected. Repeated examinations of the entire gastrointestinal tract and colon, as well as surgery in some cases, failed to disclose the cause of the pneumoperitoneum. The air was eventually absorbed in these cases and the patients were none the worse for the concern shown by the attending physicians.

A disturbing finding causing equal concern, recently observed in a patient with acute abdominal symptoms, was the presence of a radiolucent crescent shadow under the left leaf of the diaphragm which had the appearance of free air in the peritoneal cavity. Additional roentgenograms of the chest and abdomen in various projections established the fact that this shadow was not free air. This finding of simulated free air in the peritoneal cavity was given the descriptive term "pseudopneumoperitoneum."

PRESENT INVESTIGATION

Since this initial observation other cases have been seen having a similar radiolucency under the left leaf of the diaphragm simulating free air in the peritoneal cavity. The first case of pseudopneumoperitoneum is of special interest since the patient was admitted to the hospital with acute abdominal symptoms. A brief summary of this case follows.

REPORT OF A CASE

CASE 1. W.S. This thirty year old white male was admitted to the hospital two days after the onset of abdominal cramps. The abdominal cramps continued until the day of admission when he started to vomit greenish-yellow material. The patient had several loose bowel movements and a low grade fever since the onset of his illness.

On admission the patient complained of pain just above the umbilicus, whereas the day be-

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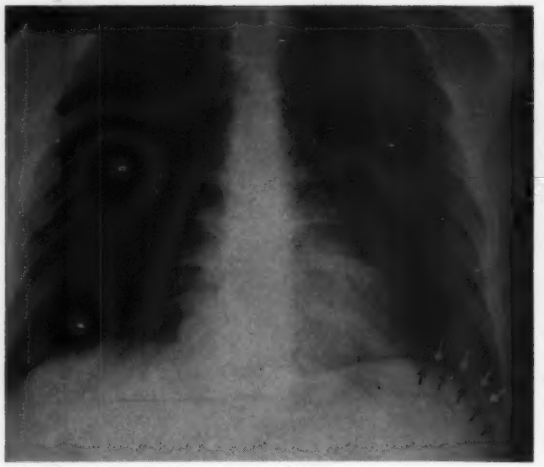

FIG. 1. Case I. Upright roentgenogram of the chest shows a crescent-shaped simulated free air shadow under the left leaf of the diaphragm due to a fat pad.

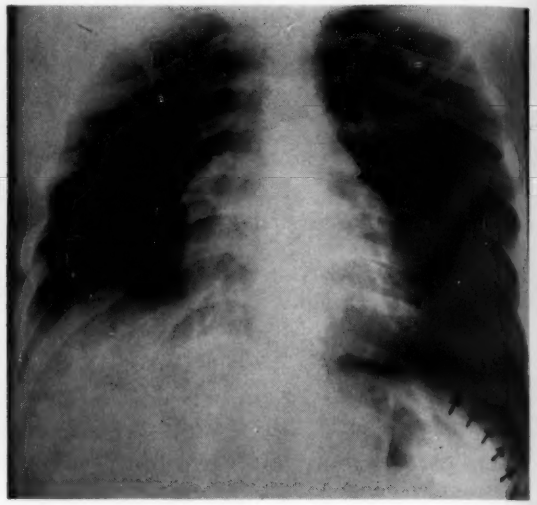

FIG. 2. Case I. Right lateral decubitus roentgenogram of the chest shows that the radiolucent shadow under the left leaf of the diaphragm has not changed position. Compare with Figure 1. A fluid level is seen in the stomach and barium is present in the splenic flexure of the colon.

fore admission the pain was localized to the small of his back. He admitted having similar attacks of abdominal pain in the past several years. The history was not entirely reliable since the patient was emotionally unstable.

Physical examination revealed a white male who appeared to be in acute abdominal distress, particularly when attended by a physician. He reacted dramatically to minor procedures, such as venipuncture and rectal examination. His abdomen was flat and soft to palpation and hypoactive peristalsis was present on auscultation. The upright chest roentgenogram taken for the detection of free air under the diaphragm showed a crescent-shaped radiolucency under the left leaf of the diaphragm, which was felt to represent a small amount of free gas in the peritoneal cavity (Fig. 1). The supine film failed to show this shadow. Since the physical findings were not in keeping with the roentgenographic findings and since the patient exhibited psychoneurotic tendencies, he was treated conservatively. The patient improved dramatically, being symptom-free the following morning. Roentgenograms of the abdomen at this time again revealed the radiolucency under the left leaf of the diaphragm. A right lateral decubitus roentgenogram of the lower chest and upper abdomen (Fig. 2) established the fact that this radiolucent shadow was constant and did not shift with change in the position of the patient. Abdominal and chest films of this patient three months later showed exactly the same findings. Because of these findings it was postulated that the subdiaphragmatic radiolucency was due to a fat pad.

FIG. 3. Case II. Upright roentgenogram of the chest taken five years following a left lower lobe resection for bronchiectasis. Note the simulated free air shadow under the left leaf of the diaphragm.

PSEUDOPNEUMOPERITONEUM DUE TO A FAT PAD

In order to establish the incidence of a fat pad under the left leaf of the diaphragm, the chest and/or abdominal roentgenograms of 600 patients were reviewed. In 7 cases, including Case 1, a radiolucency was present under the left leaf of the diaphragm sufficiently prominent to have been confused with free air in the peritoneal cavity had these individuals been examined for acute abdominal symptoms. All of these patients had roentgenographic studies for something other than acute abdominal symptoms, except for the initial case already presented. The incidence of a significant fat pad under the left leaf of the diaphragm, therefore, was found to be approximately 1 per cent.

Examination of the diaphragm in 40 cadavers disclosed the following findings: in 1 cadaver a prominent fat collection was present along the lateral aspect of the dome of the diaphragm on the left side; another showed a layer of fat along the posterolateral aspect of both leaves of the diaphragm. The fat layers in both cases were felt to be of sufficient thickness to cast a shadow on the roentgenogram provided the roentgen beam passed tangentially to them. The diaphragm in the other 38 cadavers failed to show any significant fat deposits that might be expected to cast a shadow on the roentgenogram.

Roentgenographic visualization of a fat pad of adequate thickness under the left leaf of the diaphragm depends on tangential projection of the pad, which, in turn, depends on the position of the pad and the phase of respiration in relation to the angle of roentgen-ray projection. Thus, a posterior fat layer may simulate air under the diaphragm when projected on the film from a high tube position (as on an anteroposterior roentgenogram of the chest) and an anterior fat layer is apt to simulate a streak of gas when projected from a low tube position (as on an anteroposterior roentgenogram of the abdomen). A fat pad under the dome may simulate air when the central beam is at the level of the diaphragm. Obviously, a fat pad may be seen on one projection and not on another. When this occurs on the upright film and not on the supine film, then there is reason

Fig. 4. Case v. Upright roentgenogram of the chest shows a prominent fat pad casting a radiolucent shadow under the left leaf of the diaphragm.

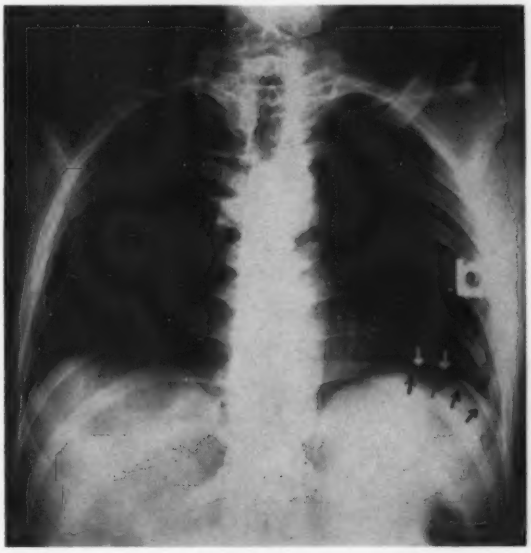

Fig. 5. Case vi. Supine roentgenogram of the chest. Arrows point to a prominent fat layer under the left leaf of the diaphragm.

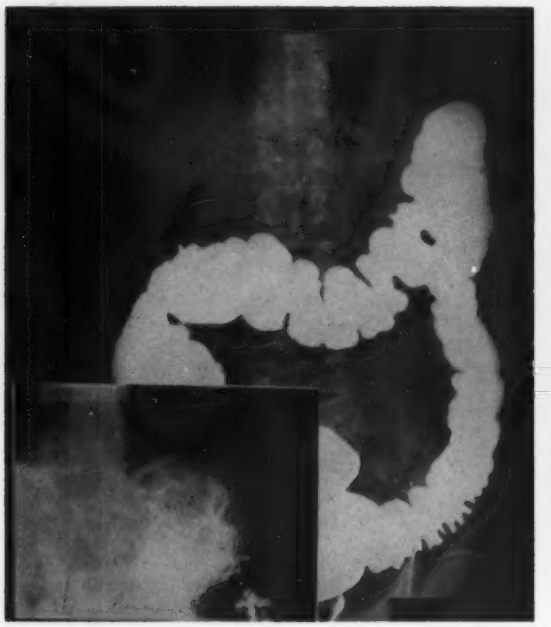

FIG. 6. Case VII. A crescent-shaped radiolucency is present under the medial aspect of the left leaf of the diaphragm. Insert indicates that the radiolucency is not gas within the stomach.

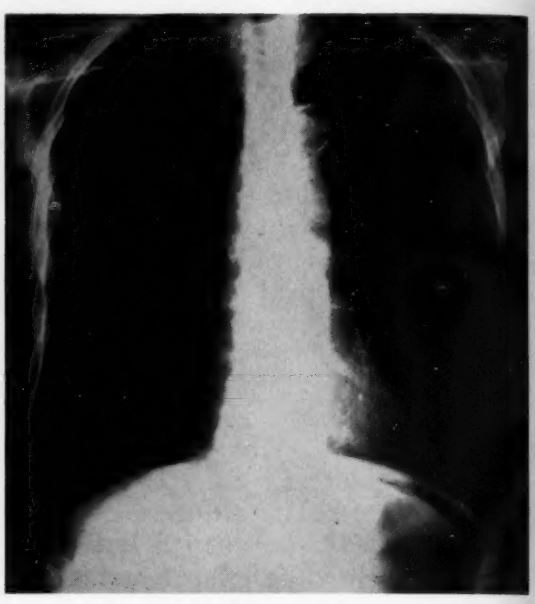

FIG. 8. Case IX. Upright roentgenogram of the chest shows the left leaf of the diaphragm projected at two different levels so as to simulate free air in the peritoneal cavity. The gas-filled fundus of the stomach outlines the under surface of the irregular left leaf of the diaphragm.

for concern, since it may be confused with free air in the peritoneal cavity.

In 6 of the 7 cases of pseudopneumoperitoneum due to a fat pad, the radiolucency was along the lateral aspect of the dome of the left leaf of the diaphragm (Fig. 1–5). In 1 case (Case VII, Fig. 6) the fat pad was along the medial aspect of the left leaf of the diaphragm. The fat pad extended posteriorly in 5 cases, since it was seen on the chest roentgenograms as well as the roentgenograms of the diaphragm. In 2 cases the fat collection extended anteriorly along the under surface of the left leaf of the diaphragm, since it was seen on the abdominal roentgenograms and not on the chest roentgenograms.

FIG. 7. Case VIII. Upright roentgenogram of the chest shows a fluid level in the stomach and a double contoured left leaf of the diaphragm simulating free air in the peritoneal cavity.

PSEUDOPNEUMOPERITONEUM DUE TO AN IRREGULAR DIAPHRAGM

From this same series of 600 cases, 4 showed changes in the left leaf of the diaphragm so as to simulate free air in the peritoneal cavity (Fig. 7–13). These changes consisted of a wavy irregularity or lobation of the left leaf of the diaphragm. This type of pseudopneumoperitoneum is due to an irregular leaf of the diaphragm projected onto the roentgenogram at two different levels with aerated lung projected below

FIG. 9. Case IX. Right lateral roentgenogram of the chest shows the lobated left leaf of the diaphragm. Same case as Figure 8.

FIG. 10. Case X. Upright roentgenogram of the diaphragm shows an apparent free gas collection under the left leaf of the diaphragm. Arrows point to the fundus of the stomach which contains a small amount of gas and a fluid level.

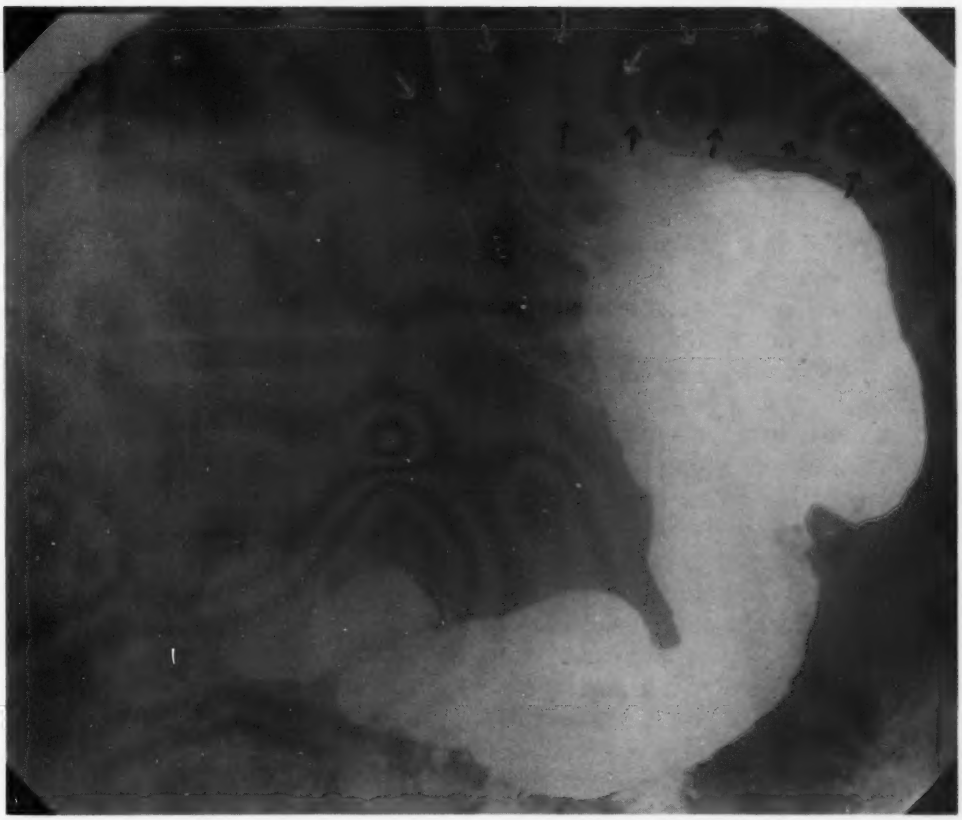

FIG. 11. Case X. Oblique view roentgenogram of the left upper abdomen with barium in the stomach. The wavy, lobated left leaf of the diaphragm (arrows) produced the pseudopneumoperitoneum seen in Figure 10.

FIG. 12. Case XI. Upright roentgenogram of the chest shows a simulated free air shadow under the left leaf of the diaphragm due to a lobated left leaf of the diaphragm (short arrow). The lateral view is shown in Figure 13. Note the interposed colon between the liver and right leaf of the diaphragm (long arrow).

the upper level of the diaphragm. This is illustrated by a diagrammatic sketch in Figure 14. If there is considerable gas within the fundus of the stomach or splenic flexure of the colon, then both sides of the irregular diaphragm may be seen, the upper surface contrasted by lung and the under surface outlined by gas within the stomach or colon. When this occurs, the simulated free air collection under the left leaf of the diaphragm is more striking, than when the under surface of the diaphragm is not contrasted by gas within the stomach or colon.

The incidence of pseudopneumoperitoneum due to an irregular left leaf of the diaphragm was found to be 0.5 per cent in the 600 cases reviewed. The irregular or lobated appearance of the diaphragm may be explained on a congenital or developmental weakness in the musculature of the diaphragm, or secondary to intraabdominal or intrathoracic disease, *e.g.*, pulmonary emphysema.

Table 1 gives some of the pertinent data in 11 cases of pseudopneumoperitoneum, 7 due to a fat pad and 4 due to an irregular left leaf of the diaphragm. Roentgenographic illustrations are indicated in this table.

DISCUSSION

It is a rule to look for free air in the peritoneal cavity in each patient admitted to the hospital with an "acute abdomen." Since free air in the peritoneal cavity may not be demonstrated roentgenographically in a significant percentage of cases with a perforated hollow viscus, careful scrutiny of the roentgenograms in the less obvious

FIG. 13. Case XI. Left lateral roentgenogram of the chest shows the lobated left leaf of the diaphragm. The gas-filled fundus of the stomach is located posteriorly (short arrow). The gas-filled hepatic flexure of the colon interposed between the right leaf of the diaphragm and liver is seen anteriorly (long arrow).

Table I

Case	Age	Sex	Reason for Roentgen Examination	Diagnosis	Cause of Pseudo-pneumo-peritoneum	Roentgeno-graphic Illustrations
I (W.S.)	30	M	abdominal pain, fever, diarrhea	gastroenteritis	fat pad	Fig. 1 and 2
II (B.C.)	18	F	cough, hemoptysis	bronchiectasis	fat pad	Fig. 3
III (D.S.)	42	F	cough, fever	lung abscess	fat pad	—
IV (J.Z.)	30	M	diarrhea	regional ileitis	fat pad	—
V (S.S.)	3	M	cough, fever	upper respiratory infection	fat pad	Fig. 4
VI (F.H.)	30	M	back pain	rheumatoid arthritis	fat pad	Fig. 5
VII (R.R.)	63	M	diarrhea, rectal pain	anorectal fistula, diverticula of colon	fat pad	Fig. 6
VIII (L.D.)	58	M	weight loss, fever	diabetes mellitus, fever of unknown origin	irregular left leaf of diaphragm	Fig. 7
IX (N.G.)	69	M	dysphagia	carcinoma of lower esophagus	irregular left leaf of diaphragm	Fig. 8 and 9
X (L.M.)	69	M	abdominal pain	diverticula and diverticulitis of colon	irregular left leaf of diaphragm	Fig. 10 and 11
XI (O.T.)	40	F	cough, weakness	upper respiratory infection, iron deficiency anemia	irregular left leaf of diaphragm	Fig. 12 and 13

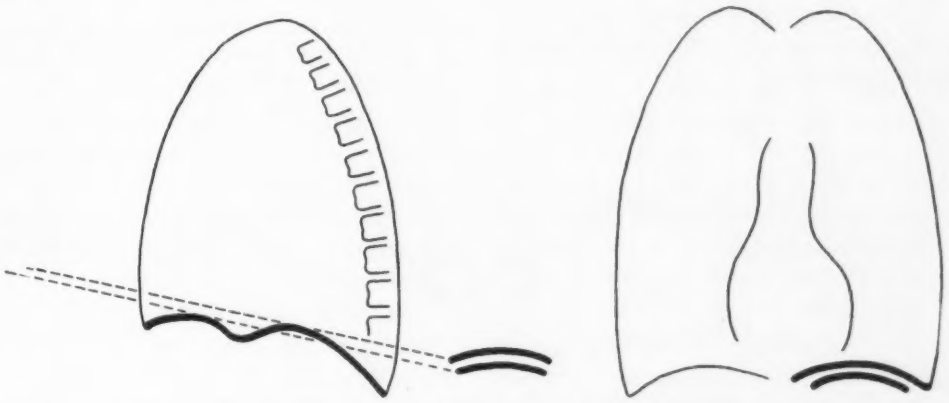

Fig. 14. Diagrammatic sketch showing the lobated left leaf of the diaphragm projected at two different levels so as to simulate a free air collection in the peritoneal cavity.

cases is necessary in an effort to detect the slightest amount of free air. The presence of of a fat pad under the left leaf of the diaphragm might lead one to an erroneous diagnosis of a small amount of free air in the peritoneal cavity. Roentgenograms of the diaphragm taken in various projections establish the constancy of this radiolucent shadow and the diagnosis of pseudopneumoperitoneum.

Undoubtedly, a fat pad radiolucency under the diaphragm is disregarded or overlooked on chest or abdominal roentgenograms of patients without acute abdominal symptoms. However, should the same findings be present in a patient with an "acute abdomen" the tendency to ignore this shadow would be less likely. Incidentally, none of the patients showing a fat pad under the left leaf of the diaphragm was obese.

The second type of pseudopneumoperitoneum due to a wavy irregularity or lobation of the left leaf of the diaphragm may be just as misleading as the type just described. Fortunately, the 4 patients exhibiting this type of pseudopneumoperitoneum had roentgenographic studies for something other than acute abdominal symptoms, so there was no immediate decision to be made. Instead, thorough roentgenographic and fluoroscopic studies were possible and the true nature of the simulated intraperitoneal free air collections was disclosed. Had these patients presented themselves with acute abdominal symptoms, it is possible that unnecessary surgery might have been performed.

SUMMARY

1. The term "pseudopneumoperitoneum" is used in this paper to describe simulated free air in the peritoneal cavity seen roentgenographically.

2. Eleven such cases have been presented, 7 due to a fat pad under the left leaf of the diaphragm, and 4 due to an irregular left leaf of the diaphragm. Both types have been discussed and the incidence of occurrence indicated.

3. The recognition of the true nature of this finding is important for accurate diagnosis, since unnecessary surgery is eliminated in such individuals being investigated for acute abdominal symptoms.

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Grateful acknowledgment is made to Dr. Gustavus C. Bird, Jr., and Dr. Herbert M. Stauffer for their criticism and advice.

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A ROENTGENOLOGIC METHOD FOR EVALUATION OF THE LARYNX AND PHARYNX

I. TECHNIQUE OF EXAMINATION

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ROENTGENOLOGIC examination of the larynx and pharynx can yield valuable information as to the site of origin and extent of a given lesion, particularly when the problem is that of management of neoplastic disease. This examination, however, is frequently neglected by the clinician as a part of the patient's general work-up. Many articles have been published stressing the importance of roentgenologic procedure in the evaluation of the larynx and pharynx. It is the purpose of this paper to outline a technique which has been used for about three years in over 100 patients and has proved quite satisfactory both for completeness as well as ease of performance.

The roentgen examination is carried out in four phases according to an established routine which requires only twenty to thirty minutes of the patient's time.

FIG. 1. The first phase of the roentgen examination of larynx and pharynx. Laminagraphic study of the larynx in anteroposterior position.

The *first phase* of the examination consists of laminagraphy of the larynx in horizontal, anteroposterior postion (Fig. 1). With the patient supine on the roentgenographic table, the roentgen tube is centered on the superior notch of the thyroid cartilage. Care is taken to keep the sagittal mid plane of the head and neck accurately perpendicular to the table. A lead clamp may be used to maintain the patient's position. An 8×10 inch roentgen cassette is centered relative to the roentgen tube in the Potter-Bucky tray of the roentgenographic table. A measurement is then made from the skin surface over the thyroid cartilage to the table top. From this measurement, the proper laminagraphic section is calculated. The first laminagraphic layer is taken at a level of 2 cm. below the anterior skin surface over the thyroid cartilage. One roentgenogram is made during a slow deep inspiration by the patient (Fig. 2*B*). A second roentgenogram is made at the same level as the patient continually phonates the vowel "E" (Fig. 2*A*). One must be certain that the patient phonates constantly during the roentgen exposure so that clear outline of the vocal cords is obtained. Care also must be taken to assure complete relaxation of the patient during the inspiratory roentgenogram in order to show the vocal cords during complete abduction. Incomplete abduction due to incomplete relaxation on the part of the patient could simulate vocal cord paresis to one not familiar with normal variants as seen laminagraphically. Roentgenoscopy, the third phase of the examination, enables one to interpret the minor variations which may be seen laminagraphically. A second

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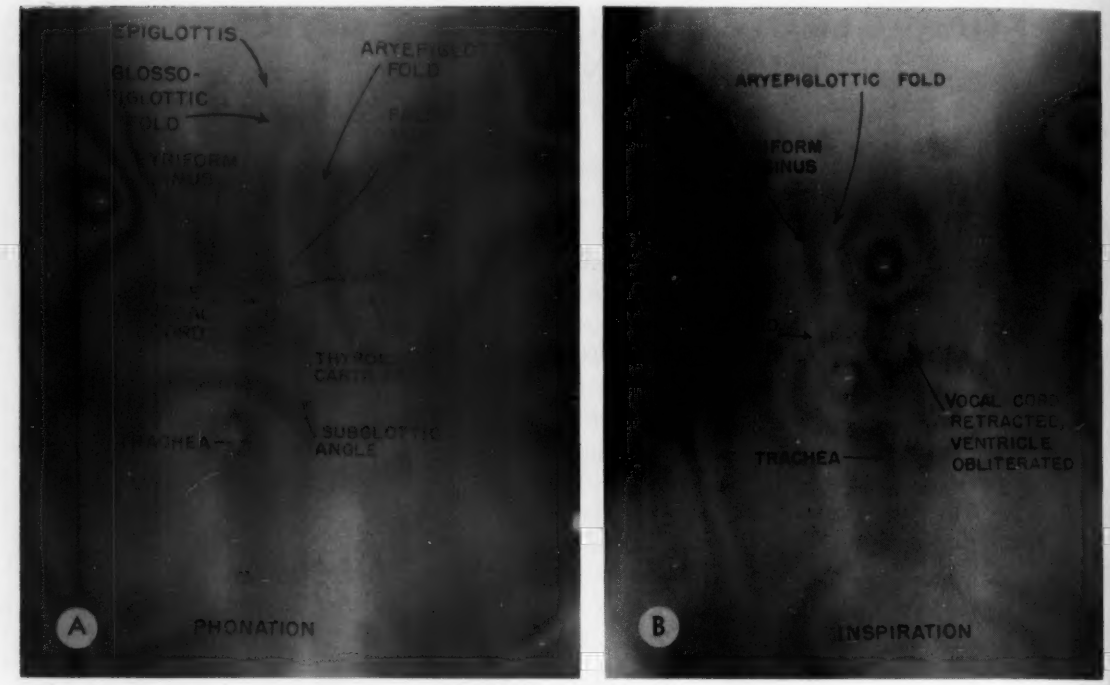

Fig. 2. Frontal laminagram during phonation (*A*) and inspiration (*B*). (Reproduced by permission of *Cancer*.[1])

pair of roentgenograms are made 3 cm. below the anterior skin surface during phonation and inspiration as with the first two roentgen exposures. Usually these four roentgenograms will give all necessary information as to the anatomy of the larynx and hypopharynx in the frontal projection. Occasionally, one may need an additional laminagraphic section for sharpest detail of the vocal cords. The technical factors used in obtaining these laminagrams are as follows for the average patient: tube travel 34 degrees, 25 ma., 75 kv., two seconds, tube-film distance 40 inches. With an increase or decrease in the thickness of the neck, only kilovoltage is varied.

The *second phase* of the examination consists of a lateral soft tissue roentgenogram of the neck (Fig. 3). With the patient sitting, the shoulders are lowered by having the patient hold a sandbag in each hand with the arms and forearms in vertical position. The roentgen tube and an 8×10 inch roentgen cassette are centered to the level of the superior notch of the thyroid cartilage. This roentgenogram is also made during phonation of the vowel "E" since the laryngeal ventricles usually will be visualized and the level of the vocal cords thus located (Fig. 4). It is important to obtain a true lateral position for best visual-

Fig. 3. The second phase of the roentgen examination of larynx and pharynx. Positioning for lateral soft tissue roentgenogram of neck.

ization of the epiglottis and aryepiglottic folds. The best soft tissue roentgenogram is obtained by using as high a kilovoltage as possible with low milliampere-seconds. A 72 inch tube-film distance is employed to minimize distortion of the anatomic structures. An average roentgenographic technique for this exposure is 95 kv., one-sixtieth of a second time, and 200 ma.

The *third phase* of the examination consists of roentgenoscopy with an image amplifier (Fig. 5). Because of the excellent detail that one has with roentgenoscopic image amplification, the functional status of the larynx can be accurately evaluated.[1] Vocal cord motion is observed and one can readily demonstrate vocal cord paralysis or fixation of a vocal cord by an infiltrating neoplasm. In the lateral projection, the motion of the arytenoid cartilages can be seen as can the mechanism of swallowing. The upward motion of the larynx with posterior tilting of the epiglottis during swallowing can be observed. Disturbed motor function of the pharyngeal muscles can be estimated in various neurologic disorders. Motions of the tongue in the swallowing mechanism can be appraised. Roentgenoscopic examination is carried out in the upright position since the shoulders can be lowered to better advantage in this position, particularly when the lateral projection is used. Less roentgen exposure is necessary with the image amplifier. The roentgenoscopy is performed with 75 kv. and 1–2 ma.

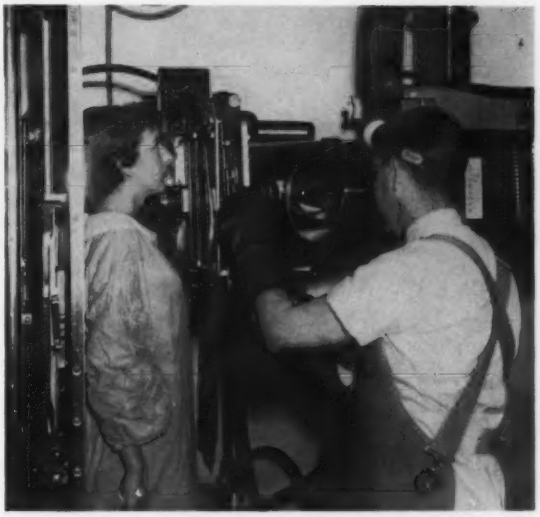

Fig. 5. The third phase of roentgen examination of larynx and pharynx. Roentgenoscopy with image amplifier gives excellent detail of larynx during function.

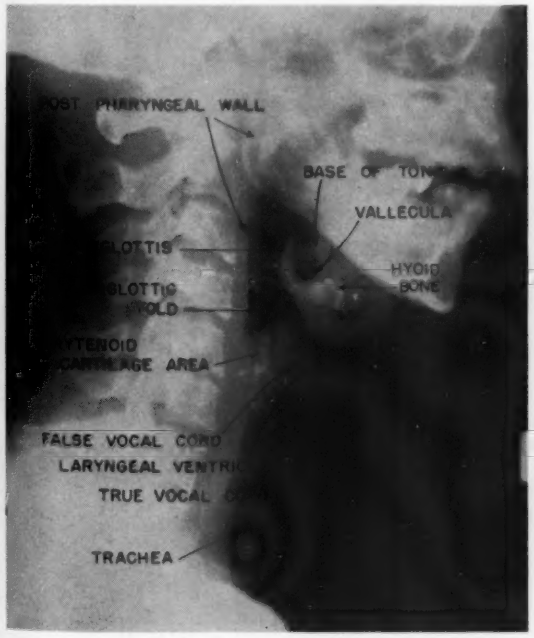

Fig. 4. Lateral soft tissue roentgenogram of neck. (Reproduced by permission of *Cancer*.[1])

The *fourth phase* of the examination consists of study of the pharynx and esophagus roentgenoscopically (Fig. 6) as the patient

Fig. 6. The fourth phase of the examination of larynx and pharynx. Ingestion of thick barium sulfate paste to give mucosal relief pattern of hypopharynx and esophagus.

Fig. 7. Normal frontal view of pyriform sinuses, outlined by thick barium sulfate paste; "spot" roentgenogram.

ingests thick barium sulfate paste—a technique recommended by Welin.[3] In the frontal projection an excellent visualization of the pyriform sinuses and lateral pharyngeal walls can be obtained after the major bolus of barium sulfate has been swallowed, there remaining a mucosal relief of the structures (Fig. 7). The extent of any mass in the hypopharynx or cervical esophagus can be demonstrated. In any neoplastic lesion of the pyriform sinus one must examine the cervical esophagus since a lesion not infrequently may arise lower in the esophagus and extend upward to the hypopharynx. Clinical examination cannot delineate the lower extension in such a case. Also posterior laryngeal lesions or subglottic neoplasms may compress or infiltrate the upper esophagus, such information being important in planning management and suggesting prognosis. It is for these reasons that barium sulfate studies of the pharynx and esophagus are a routine part of this examination. During the roentgenoscopic procedure, spot roentgenograms of the pharynx and esophagus outlined by barium sulfate are obtained. After the roentgenoscopic procedure, a lateral roentgenogram is made as outlined above in the second phase of the examination with the exception that the roentgenogram is exposed at the height of swallowing barium sulfate paste using a time of one-thirtieth of a second instead of one-sixtieth of a second. A good technician with practice can invariably obtain good roentgenograms demonstrating the cervical esophagus completely distended with barium sulfate paste (Fig. 8).

DISCUSSION

With proper roentgenographic technique, air in the larynx and pharynx serves as a good contrast material for the visualization

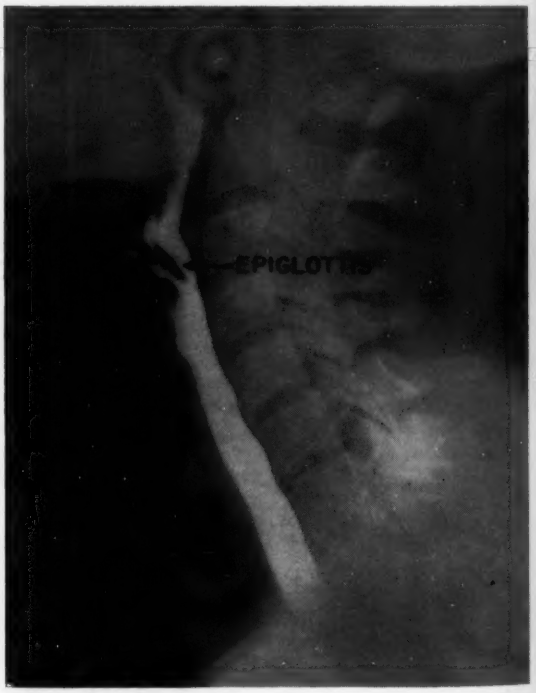

Fig. 8. Normal cervical esophagus filled with barium sulfate in lateral projection.

of anatomic structures. For an examination to be of practical value, certain requirements must be met. Safety, ease of performance, the use of standard equipment, and good definition of anatomic structures are factors which must be taken into consideration. Contrast visualization of the larynx with iodized oil has been recently recommended[2] and certainly has its merits. The detail of laryngeal structures is excellent, but any procedure requiring local anesthesia must necessarily be more time consuming as well as adding some reaction risk to the examination. The sequence of the four phases of the examination as outlined above has been found very satisfactory for routine daily office or hospital practice. All gross anatomic landmarks of the pharynx and larynx can be visualized, roentgenoscopy demonstrating the structures during function and roentgenograms serving as a permanent record of the roentgenoscopic findings. Roentgenoscopy is essential in studying the function of the vocal cords and the mechanism of swallowing.

Roentgenologic studies are not meant to compete with or replace a good clinical examination of the larynx and pharynx, but rather to complement and confirm the findings gained through direct and indirect laryngoscopy. The greatest possible amount of information is obtained by close cooperation of the clinician and the roentgenologist. The roentgenologist can occasionally demonstrate an extension of a lesion which cannot be seen clinically. This is particularly true in regard to subglottic lesions and lesions of the cervical esophagus and hypopharynx. Ulcerations may be invisible by clinical examination yet demonstrated roentgenologically. In an elderly patient where clinical examination is usually difficult, roentgenologic examination may show the extent of a lesion which, otherwise, would not be known. Roentgenologic studies are essential to the radiotherapist in planning roentgen therapy of lesions of the larynx. The procedure as outlined is valuable also in following the response of a given lesion to roentgen therapy.

SUMMARY

A roentgenologic routine for evaluation of lesions of laryngopharynx is presented. It has been found very satisfactory in daily practice of roentgen diagnosis. The routine consists of laminagraphy of the laryngopharynx in frontal projection, lateral soft tissue roentgenography of the neck, roentgenoscopy with the roentgenoscopic image amplifier, and roentgenoscopic and roentgenographic studies of the pharynx and cervical esophagus with thick barium paste.

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SUPERVOLTAGE ROENTGENOGRAPHY*

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PREVIOUS investigators have established the technical feasibility of supervoltage roentgenography, i.e., the preparation of roentgenograms with rays generated at or above 1,000 kv. peak, and have pointed to possible indications for its use.

The limited availability of supervoltage roentgen ray machines at this time makes a widespread use of this technique unlikely, regardless of its merits. Nevertheless, it is felt that the accumulation of further experience in this field is justified in order to assess its clinical value. Our interest in this field was prompted initially by a desire to improve the quality of the roentgenograms used for beam alignment in connection with 1,000 kv. rotation therapy. The scope of this investigation was subsequently extended to include evaluation of the practical aspects of supervoltage diagnostic roentgenography. Various normal and abnormal features of the supervoltage roentgenograms have been compared with those on corresponding conventional films and with the findings at operation or autopsy. The purpose of this discussion is to describe the use of the supervoltage techniques in roentgen diagnosis.

HISTORICAL BACKGROUND

Supervoltage roentgenography dates back to 1945 when Mermagen[6] described a human chest roentgenogram made with a 1,000 kv. industrial roentgenographic unit and reported it "merely as a matter of interest." The time required for exposure of this film was thirty seconds, which automatically precluded its clinical application as a practical diagnostic procedure. In 1951 Hare *et al.*[5] utilized supervoltage roentgenograms for beam localization in the therapy of pituitary tumors. They pointed out "the good delineation of air passages and relatively faint but sufficient contrast between bone and soft tissues," and predicted the use of this technique for the detection of lung tumors and also of bladder and rectal tumors after air insufflation.

Tuddenham, Hale, and Pendergrass[8] in 1953 described a technique for supervoltage diagnostic roentgenography of the chest utilizing a 1,000 kv. machine operated at 3 ma. for seventeen seconds with a target-film distance of 72 inches. They stressed its potentialities as an aid in earlier diagnosis of lesions of the chest and other air-bearing structures. Their technique was subsequently refined to the point where the exposure time for a chest roentgenogram was reduced to 2 seconds plus build-up time. In 1954 Tuddenham *et al.*[9] in describing additional experiences with supervoltage technique concluded that the air-containing structures of the mediastinum are consistently demonstrated to better advantage on the supervoltage roentgenograms; that this facilitated the recognition of lesions involving those structures; and that certain pulmonary abnormalities producing focal changes in aeration could be more clearly outlined. They used a 2,000 kv. Van de Graaf generator operating at 100 microamperes and a target-film distance of 56 inches. All exposures were made on Ansco Superay C X-ray Film or Kodak No-Screen X-ray Film between lead-antimony intensifying screens 0.005 inches thick. They considered their efforts sufficiently rewarding to warrant further investigation. In 1954 Friedman,[3] using a similar technique for beam localization in 2,000 kv. rotational therapy, emphasized the diagnostic value of the roentgenogram obtained.

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TECHNICAL ASPECTS

The roentgenographic equipment used in this study is the 1,000 kv. resonant transformer in the Radiation Therapy Department at Walter Reed Army Hospital. This machine, which has not been modified for roentgenography, has a focal spot of 1.2 cm. in diameter. The target-film distance of 140 cm. was arbitrarily selected because of spatial arrangements of the therapy room. The roentgen ray beam is horizontally directed for most examinations with the patient upright. A juxtapositional, gravity-activated lead shutter shielding the film during the build-up period of six to eight seconds in which the operating level of 3 ma. is reached, has been used occasionally. However, for most examinations the build-up time has been included in the exposure, since this method technically seemed to be satisfactory. The exposure in milliampere-seconds for various parts is as follows: Chest—6 to 8; nasopharynx—15; abdomen—20.

Kodak No-Screen Film encased between lead screens 0.005 inches to 0.02 inches in thickness in place of conventional intensifying screens has been used for the majority of the examinations. A better image is produced in examinations of the chest and abdomen when the back screen of the casette is 0.02 inches thick, the thickness of the front screen being retained at 0.005 inches. For the examinations of the head and neck, however, it seems that nothing is gained by increasing the thickness of the back screen beyond 0.005 inches. Conventional procedures for Kodak No-Screen Film in liquid developer are used in processing these films. The exposure to the patient is less than 1 r for a chest roentgenogram, about 1.5 r for a roentgenogram of the head, and less than 2 r for an abdominal roentgenogram.

The mechanism of image production has not been completely explained. The image probably results from the secondary photoelectrons from the lead screens. It appears that the backscatter from the back screen plays a more important role in image definition than that from the front. A simple test was used to measure the relative importance of the two screens. When masking tape or cardboard was interposed between the back screen and the film, no image was produced in the affected area, but film fog was not eliminated. When the masking tape or cardboard was placed between the front screen and the film, no alteration of image was discernible. The image was not materially altered when additional lead, up to 0.04 inches in thickness, was placed on either side of the film.

The size of the focal spot of the target is not an important factor in producing sharpness of image definition with the supervoltage technique. Comparison of films of a test object made with our machine with a focal spot of 1.2 cm. and those made with a generator having a focal spot of 0.5 mm. shows no detectable difference in sharpness of definition.[10]

ROENTGENOGRAPHIC INTERPRETATION

The outstanding features of the supervoltage roentgenograms are the almost uniform density of the solid tissues and the marked contrast between tissue and air density. As pointed out by Wachsman (quoted by Tuddenham *et al.*[9]) the disparity between the absorption of irradiation by various tissues, especially that between bone and fat, is high at lower qualities of radiation and is gradually reduced as the kilovoltage is increased until the differential tissue absorption ratio closely approaches unity at 1,000 kv. At that point the shadows of bone on films are barely noticeable, and the air-containing structures stand out clearly. Diagnostic capabilities can be extended not only in and about the normally air-containing parts but also in those structures where air can be introduced as a contrast medium. The relationship of the various tissue densities to quality of irradiation is shown in Figure 1. It will be noted that the shadows of bones become less prominent as the kilovoltage is increased.

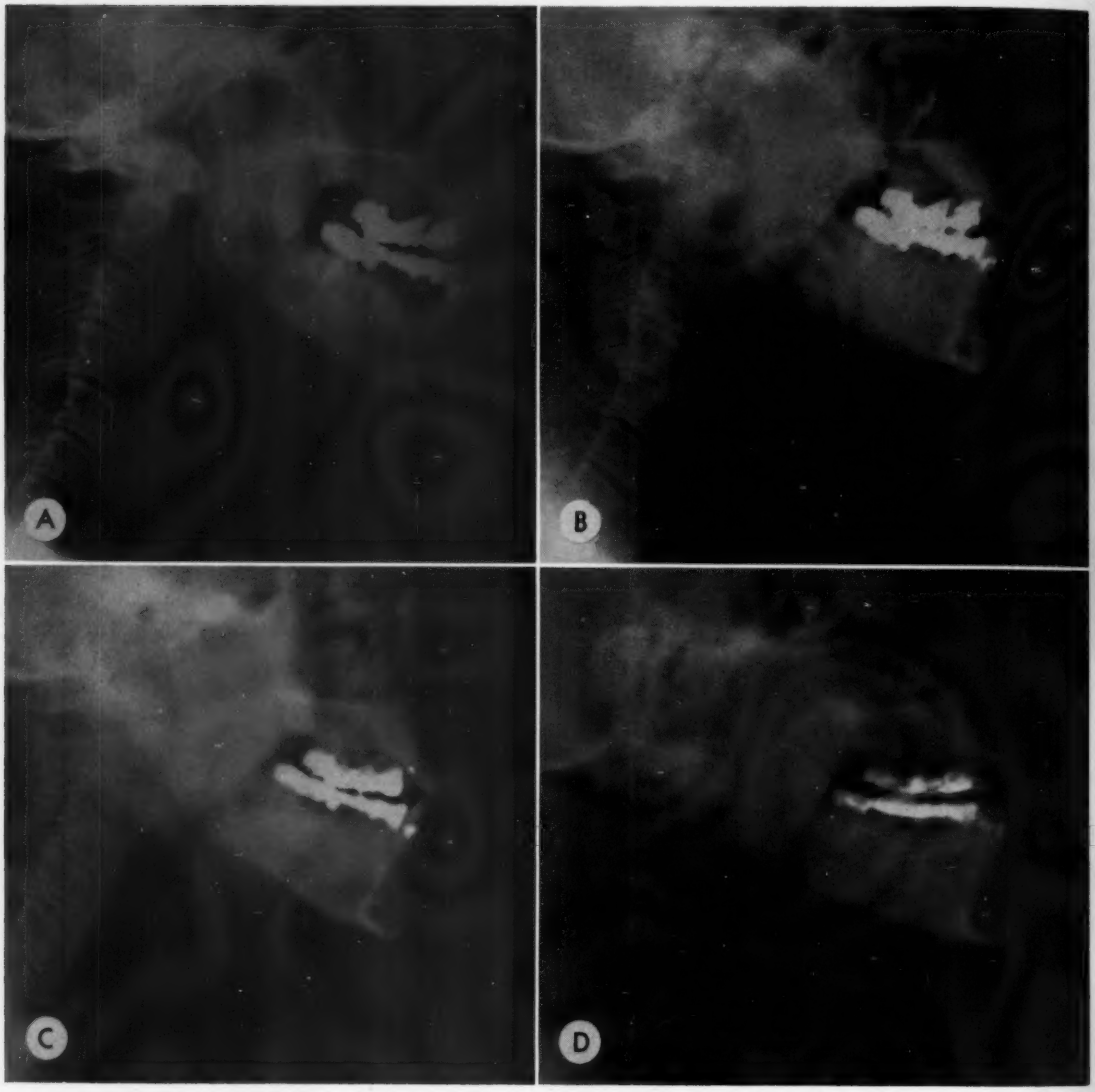

FIG. 1. The relationship between tissue densities and quality of irradiation. (*A*) 70 kv., 100 ma., Ansco High-Speed Film. (*B*) 130 kv., 100 ma., Kodak No-Screen Film. (*C*) 200 kv., 100 ma., Kodak No-Screen Film. (*D*) 1,000 kv., 15 ma., Kodak No-Screen Film.

CHEST

The contrast between the air-containing structures and the solid tissues is noteworthy in the examination of the lungs and is especially striking in the mediastinum (Fig. 2). The ribs and spine are only faintly visible. The larynx, trachea, and bronchi are distinctly outlined, as are the medial borders of the lungs superimposed on the shadow of the heart, their inferior margins below the domes of the diaphragm, and the contact of the pleuras of both hemithoraces anterior to the great vessels in the superior mediastinum. The medial border of the right lung superimposed on the heart shadow assumes the form of a vertical, straight line, located behind the heart and to the left of the mid-line, where the pleura is in contact with the esophagus. The medial border of the left lung has been associated with the posteromedial pleural line of Garland[4] and is not uncommonly seen on con-

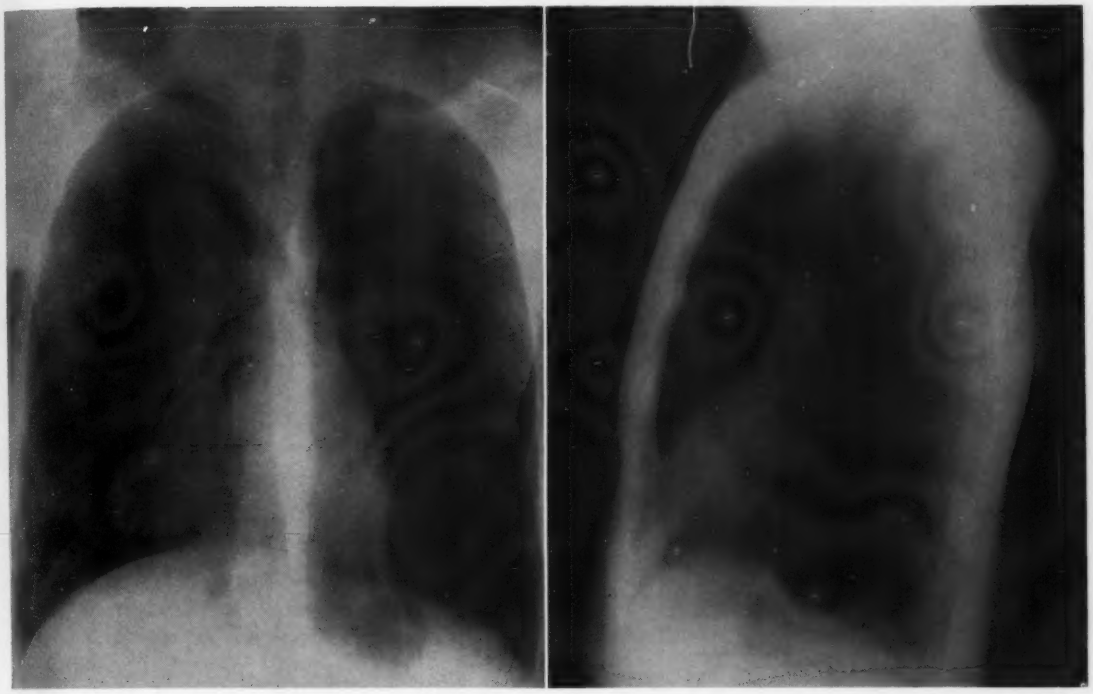

Fig. 2. Supervoltage roentgenograms of a normal chest. Note indistinctness of bone shadows, tracheal and bronchial air columns, contact of pleuras superimposed over trachea, medial margins of lungs superimposed on cardiac shadow, and inferior lung margins below diaphragmatic outlines in the posteroanterior view.

ventional, overpenetrated chest roentgenograms. However, the medial border of the right lung is not easily seen because of the overlying densities of the heart and thoracic spine. On the supervoltage roentgenogram it stands out clearly and becomes an important diagnostic landmark. Actually two medial margins of the shadow of the left lung are visible on these films, one in contact with the descending aorta and another slightly medial to the first in contact with the esophagus.

The contact of the pleuras in front of the branches of the arch of the aorta appears as an x-shaped shadow. It is occasionally seen in conventional chest roentgenograms as a crescentic linear shadow superimposed on the trachea. Various investigators have explained this shadow as the right pleural reflection from the esophagus, and Cimmino[1] has designated it as the esophageal-pleural stripe. However, on the supervoltage roentgenogram it appears that the anterior bilateral pleural contact is a more logical explanation.

In the lateral view of the chest, the area of lung translucency is increased by the indistinctness of the thoracic spine and the clarity of the apical regions which are usually hidden by the shoulders on ordinary roentgenograms.

If the supervoltage chest roentgenograms are to be of any value, they must be expected to show lesions not clearly demonstrable or not shown at all in the conventional films. This might be accomplished by elimination of overlapping shadows of bone or by virtue of the accentuated air-tissue contrast which the supervoltage technique affords in the mediastinum, as previously described. Small densities in the lungs and variations in aeration of the lung may be visualized, and retrocardiac and infradiaphragmatic abnormalities may be disclosed in the frontal projection by qualitative differences in density. In addition, the displacement of the medial and inferior lung margins may

FIG. 3. Case I. Endobronchial tuberculosis, right lower lobe. Zone of localized emphysema indicated by arrow.

be of diagnostic significance. These points will be illustrated in the ensuing examples.

CASE I. A fifty-four year old white woman with the clinical problem of hemoptysis had repeated chest roentgenograms over a period of about three months with no abnormalities demonstrated. The supervoltage roentgenogram (Fig. 3) disclosed an area of increased translucency adjacent to the border of the right side of the heart, which was interpreted as localized emphysema and suggested the presence of an obstructing lesion of the right lower lobe. On bronchoscopy, granulation tissue was seen in the posterior basal segment of the right lower lobe and washings were positive for tubercle bacilli, thus establishing an early diagnosis of endobronchial tuberculosis.

This case exemplifies a significant localized variation in lung aeration seen only on the supervoltage roentgenogram and playing a decisive role in diagnosis.

CASE II. A thirty-five year old white man had a malignant melanoma of the posterior surface of the left shoulder removed in October 1954. A year later enlarged left axillary lymph nodes appeared. A conventional roentgenogram of the chest at this time revealed no abnormalities. On the supervoltage roentgenogram (Fig. 4) the shadows of numerous metastases, measuring up to 1 cm. in diameter, were seen in both lungs.

Information affecting the prognosis of this patient was, therefore, available at an earlier date than might otherwise have been the case if sole reliance had been placed on the conventional roentgenogram. The elimination of rib shadows and the improved air-tissue contrast of the supervoltage roentgenogram made the metastases stand out more clearly.

CASE III. A twenty-four year old white man was noted to have a superior mediastinal mass on the conventional chest roentgenogram. The supervoltage roentgenograms (Fig. 5) showed that the mass was not limited to the superior mediastinum but extended inferiorly into the posterior mediastinum. An exploratory thoracotomy was done and this impression was confirmed. The diagnosis proved by histologic examination was Hodgkin's disease.

In this case the diagnostic findings in the supervoltage roentgenograms were based on a qualitative difference of densities superimposed on the heart shadow. The infor-

FIG. 4. Case II. Pulmonary metastases from malignant melanoma not visible on a conventional roentgenogram.

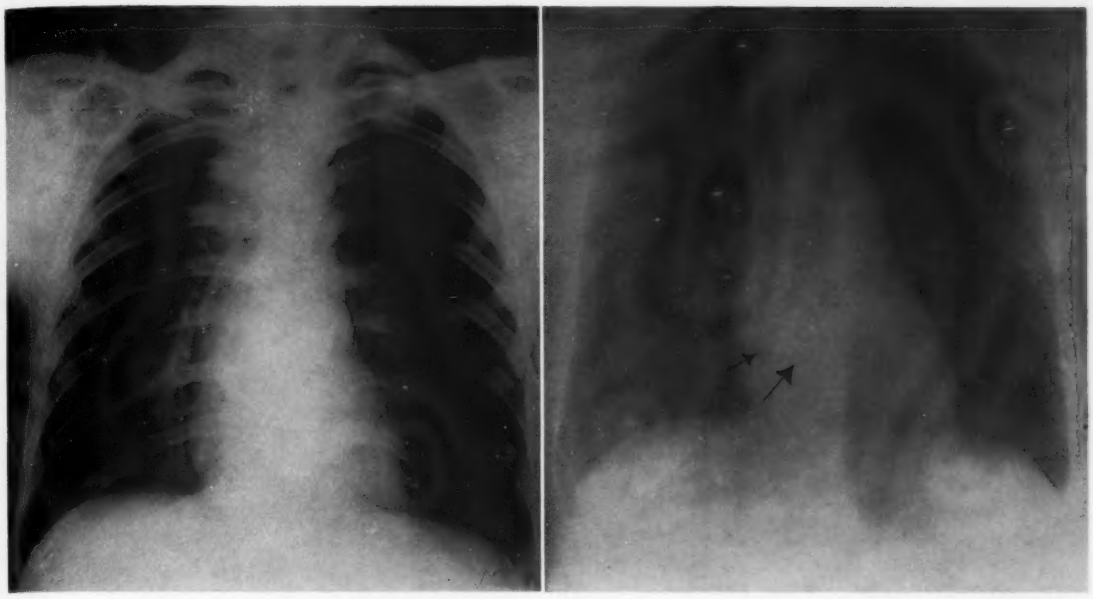

Fig. 5. Case III. Mediastinal Hodgkin's disease. Arrows indicate extension into posterior mediastinum.

mation gleaned affected the decision of the surgeon in selecting his operative procedure and assisted the radiation therapist in determining the extent of disease and the size of the treatment fields used for its irradiation.

Case IV. A forty-eight year old Negro man complained of cough, wheezing, and mild dysphagia of about three months' duration. Plain roentgenograms of the chest disclosed a widening of the superior mediastinal shadow in the frontal projection and the presence of a mass along the posterior margin of the trachea at the level of the coryna in the lateral view. This mass was seen on bronchoscopic examination as occluding the trachea along its posterior and right lateral margins, beginning about two inches above the coryna and extending downward into the right main stem bronchus. The histologic examination of tissue removed at thoracotomy yielded a diagnosis of cylindroma of the trachea. The supervoltage roentgenograms (Fig. 6) made after thoracotomy and prior to the initiation of a course of irradiation showed the location of the tumor along the right and posterior borders of the trachea, the opacification of the trachea and right main stem bronchus by the tumor in the frontal view, and the tracheal occlusion.

Although the diagnosis had already been made and treatment instituted before we saw this patient, the supervoltage roentgenograms outlined the tumor in clearer detail than did the conventional roentgenograms. The subsequent assessment of the shrinkage of the tumor and the widening of the tracheal lumen was better accomplished on the supervoltage roentgenograms.

Case V. A thirty-four year old white woman with a clinical diagnosis of coarctation of the aorta exhibited a prominent aortic knob on the conventional chest roentgenogram. However, none of the usual, pertinent roentgen signs of this condition were seen. The supervoltage roentgenograms (Fig. 7) revealed the point of stenosis and the poststenotic dilatation of the descending aorta, obviating the need for the use of intravascular contrast material.

In this case the aorta is more clearly outlined against the background of air density on the supervoltage roentgenograms than it is on the conventional roentgenogram.

Case VI. A thirty-seven year old white woman with early mitral stenosis revealed the double density of the enlarged left atrium on the conventional chest roentgenograms. The left atrium was more clearly shown on the supervoltage roentgenogram (Fig. 8) because of the diminished spine shadow and the in-

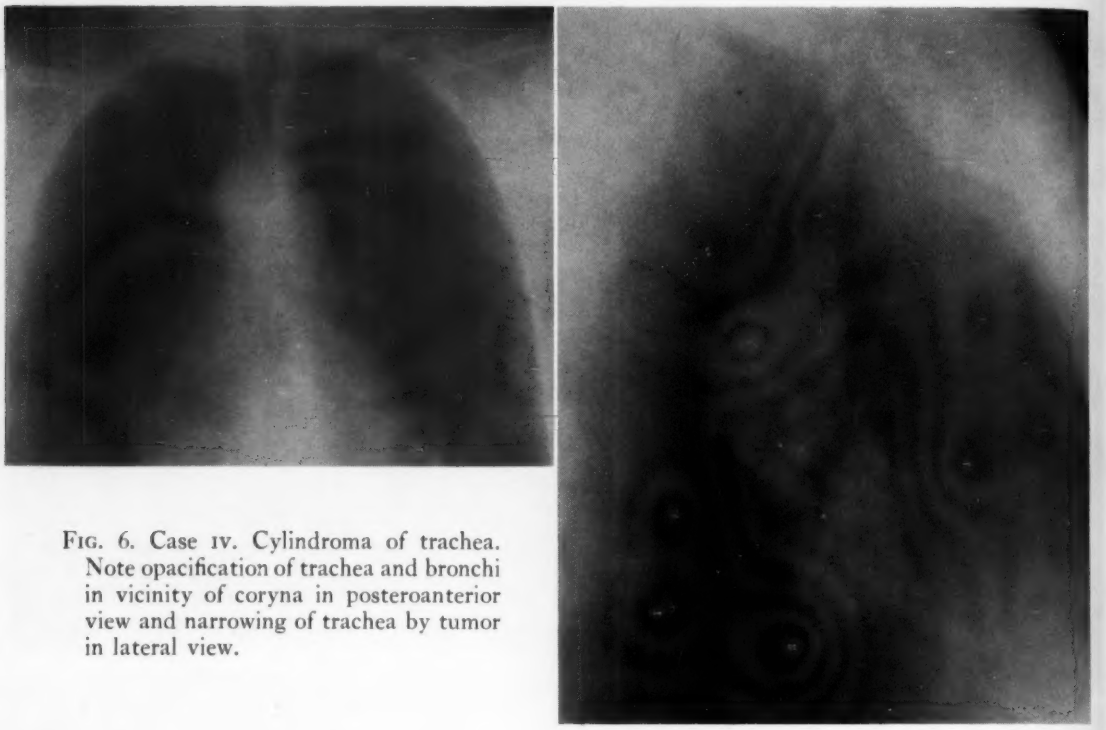

FIG. 6. Case IV. Cylindroma of trachea. Note opacification of trachea and bronchi in vicinity of coryna in posteroanterior view and narrowing of trachea by tumor in lateral view.

creased air-tissue contrast available in the mediastinum.

When the left atrium enlarges, it first expands in a posterior direction and exerts pressure at an early stage on the medial lung borders. The latter are compressed, displaced, and bowed with convexity outward. Since the medial border of the right

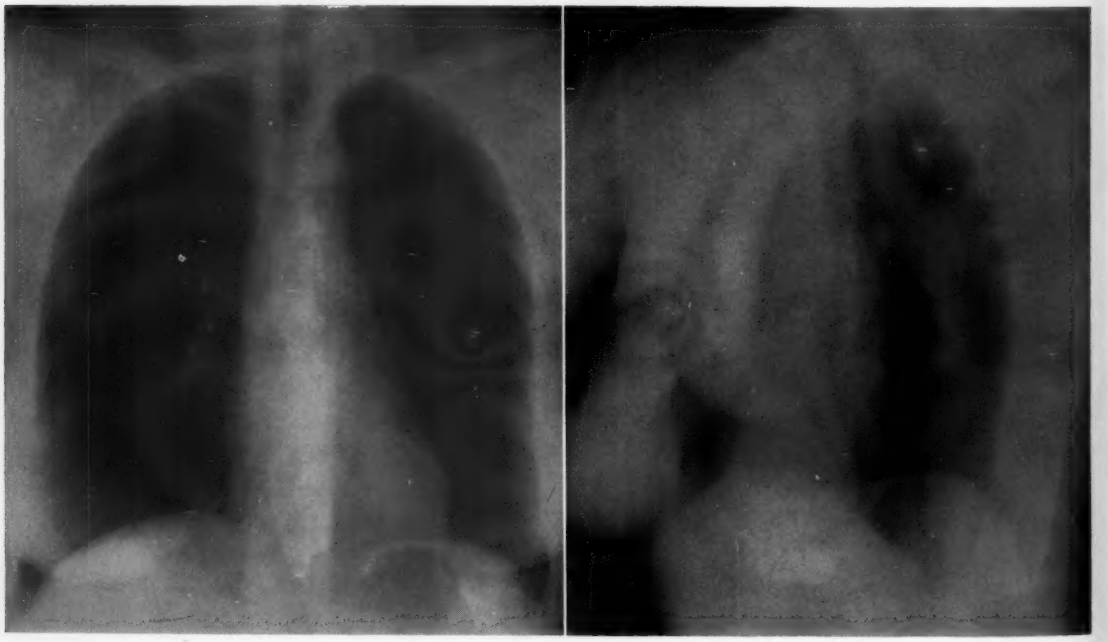

FIG. 7. Case V. Coarctation of the aorta.

lung is reached first by the enlarging atrium, the bowing of this line is likely to be the earliest roentgen sign of mitral stenosis. With marked enlargement of the left atrium the outward bowing and displacement of bronchovascular markings may be seen through the cardiac silhouette.

Case vii. A fifty-two year old white woman had a histologically proved epidermoid carcinoma of the upper third of the esophagus (Fig. 9). The conventional posteroanterior and lateral roentgenograms of the chest with barium mixture in the esophagus showed the mucosal involvement by tumor and the presence of a right superior mediastinal mass at the level of the first and second ribs. Only the inferior part of this mass was visible in the posteroanterior view, while in the lateral view only the anterior intraluminal margin of the tumor as outlined by the barium column was seen. The apical regions of the chest in the lateral projection were hidden by the shadows of the shoulders.

On the lateral supervoltage roentgenogram the mass of the tumor was seen to lie posterior to the esophagus, and in the posteroanterior view the normally outlined right pyriform sinus suggested that the upper limit of the tumor lay below it.

In this case, advantage was taken of the ability of the supervoltage roentgenogram to define the limits of the tumor by the better air-tissue contrast in the apical regions of the chest and neck.

Case viii. A twenty-four year old white woman with a six month history of masculinizing symptoms had no remarkable findings on the usual chest roentgenograms other than absence of the air bubble of the stomach, which is of dubious significance. The supervoltage roentgenograms (Fig. 10) disclosed the presence of a left subdiaphragmatic tumor which had obliterated the left inferior lung margin and was outlined by the left hemidiaphragm superiorly and the air in the stomach anteriorly. This tumor proved to be a carcinoma of the left adrenal cortex.

Although other roentgen examinations gave more information about this tumor, the possibility of eliciting significant roentgen signs of infradiaphragmatic lesions on the supervoltage chest roentgenograms adds to their value.

Fig. 8. Case vi. Mitral stenosis. Shadow of enlarged left auricle indicated by single arrow; compression of medial border of right lung by enlarged left auricle indicated by double arrow.

In recapitulation, the advantages of the supervoltage chest roentgenograms may be manifested in the following ways:

1. The accentuated air-tissue contrast with greatly diminished density of the shadows of bone permits the recognition of focal changes in aeration of the lungs and the demonstration of shadows of soft tissue density of small pulmonary lesions and of the aorta, otherwise not visible on conventional roentgenograms.

2. The extent and location of mediastinal and infradiaphragmatic lesions may be defined by qualitative differences in tissue density, their demonstrable capacity for compressing and displacing the margins of contiguous air-containing structures, and their ability to opacify and deform the shadows of the trachea and bronchi.

Nasopharynx and Larynx

Although most lesions of the nasopharynx, larynx, and laryngopharynx are susceptible to examination by inspection,

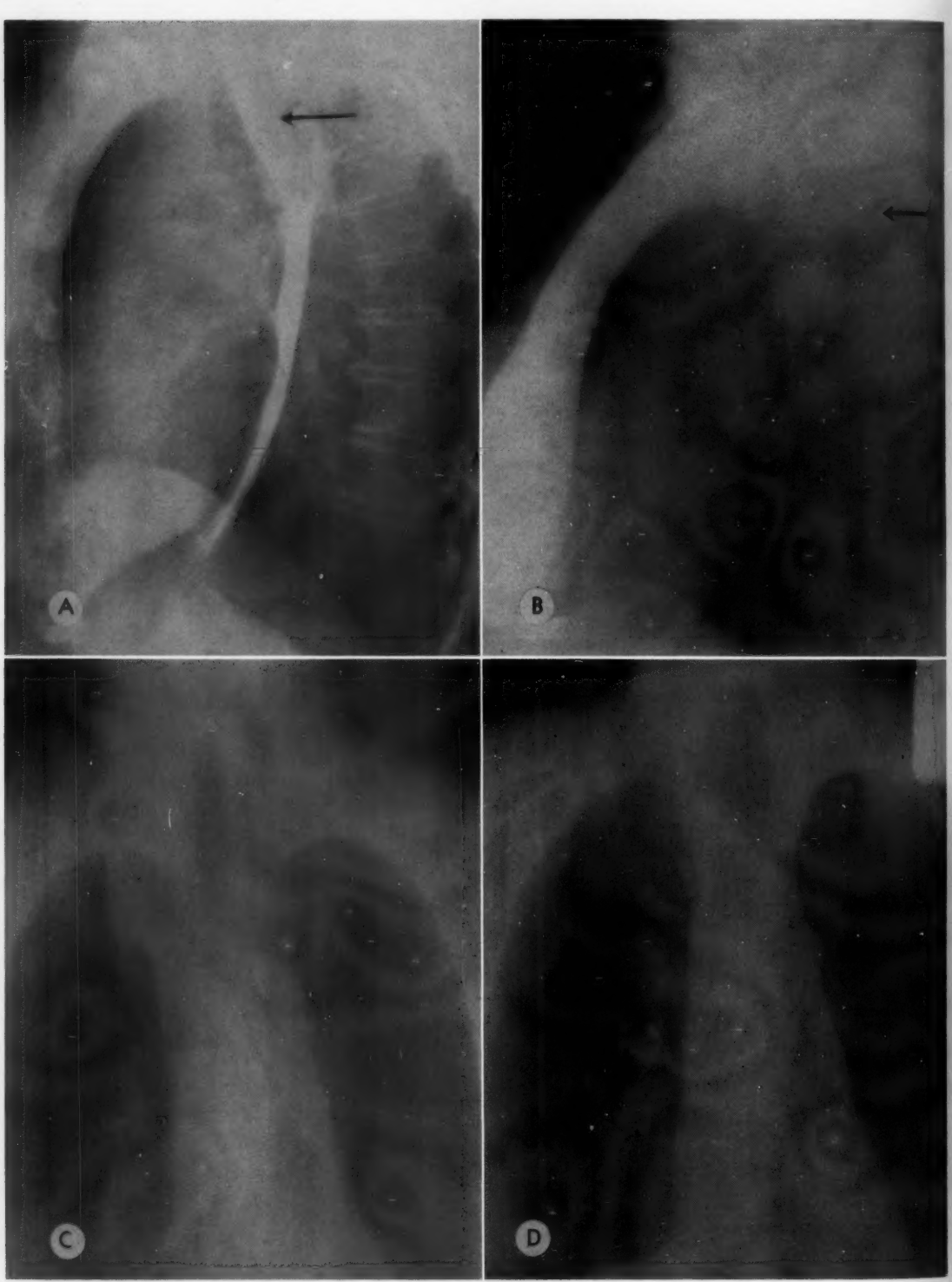

FIG. 9. Case VII. Carcinoma of the esophagus. (*A*) Intraluminal margin of tumor outlined by shadow of barium sulfate. (*B*) Posterior extension of tumor seen on the supervoltage roentgenogram. (*C*) Appearance of tumor in posteroanterior view. Note opacification of trachea, widening of superior mediastinal shadow, and normal right pyriform sinus. (*D*) Status or tumor after radiation therapy (6,000 r in fifty-two days).

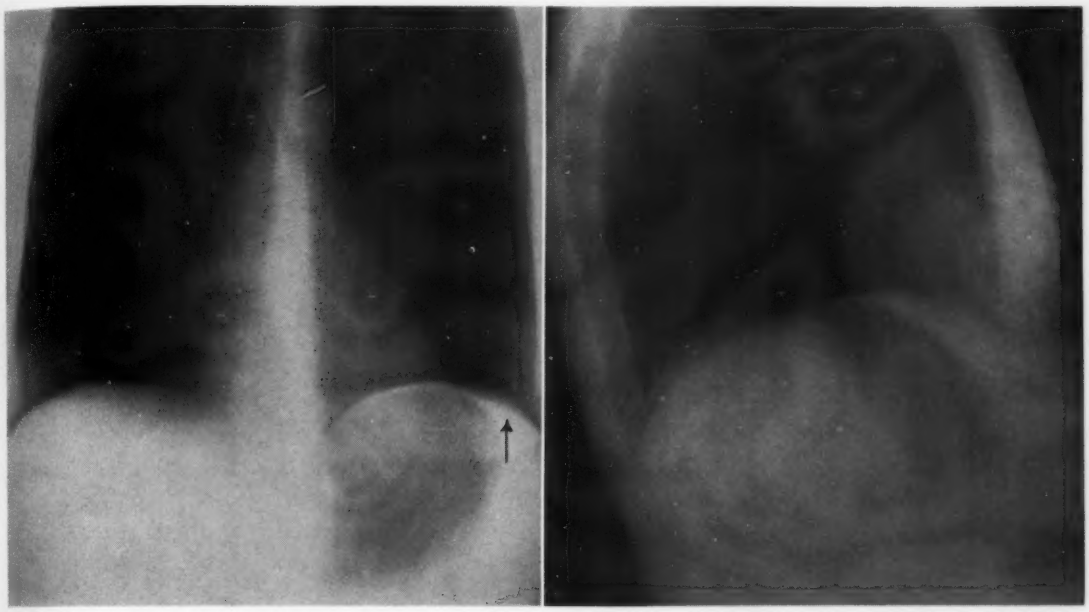

Fig. 10. Case VIII. Carcinoma of the left adrenal cortex. Note upward displacement of inferior lung margin lateral to stomach bubble (arrow) in posteroanterior view.

additional information not obtainable by this method is frequently desired.

The air-containing structures of the head and neck provide a suitable contrast for conventional roentgen examinations, but superimposition of a complex maze of shadows of the facial and cranial bones over the nasopharynx and of those of the

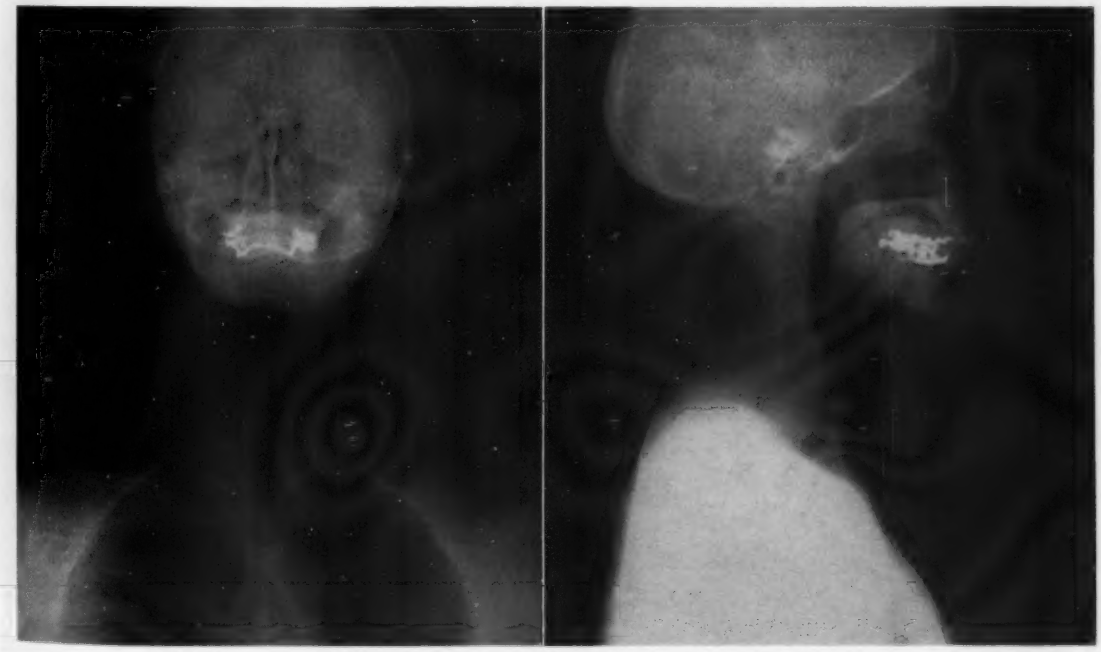

Fig. 11. Supervoltage roentgenograms of the head and neck demonstrating normal air-containing structures and contiguous parts.

FIG. 12. Case IX. Rhabdomyosarcoma of the nasopharynx.

cervical spine over the larynx obscures soft tissue details. To a certain extent, this difficulty can be obviated by laminagraphy, but this procedure requires multiple exposures and shows a limited area in a single plane on each film. The supervoltage roentgenograms of the head and neck (Fig. 11) clearly demonstrate all of the air-bearing structures with greatly diminished shadows of bone density and distinct outlines of soft tissues bordering on the air column. The nasopharynx is better studied in the lateral projection, while the larynx shows to better advantage in the frontal view.

In the lateral view of the head and neck one may see the paranasal sinuses, the turbinates, the uvula, the posterior margin of the tongue, the posterior margin of the pharynx, the roof of the nasopharynx, the pharyngeal recess, the torus tubarius, the epiglottis, valleculae, laryngeal ventricle, and trachea. In the frontal view of the neck the ventricular folds, vocal cords, and pyriform sinuses are noted. The following cases are presented to illustrate the appearance of tumors of the nasopharynx, larynx, and hypopharynx.

CASE IX. An eight year old girl had a history of left facial pain and evidence of involvement of the left third, fourth, fifth, sixth, ninth, and tenth cranial nerves of several weeks' duration. The supervoltage roentgenogram (Fig. 12) disclosed a large mass in the nasopharynx which was diagnosed histologically as an undifferentiated mesenchymal tumor, most likely a rhabdomyosarcoma.

Although this tumor could be demonstrated on conventional roentgenograms, it stood out more clearly on the supervoltage roentgenogram.

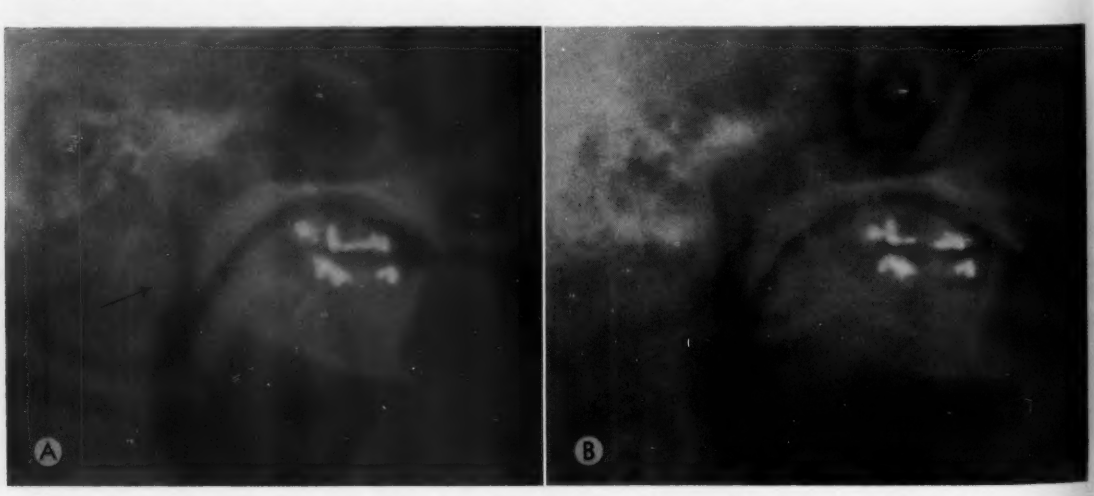

FIG. 13. Case X. Carcinoma of the oropharynx and nasopharynx before (*A*) and after (*B*) radiation therapy.

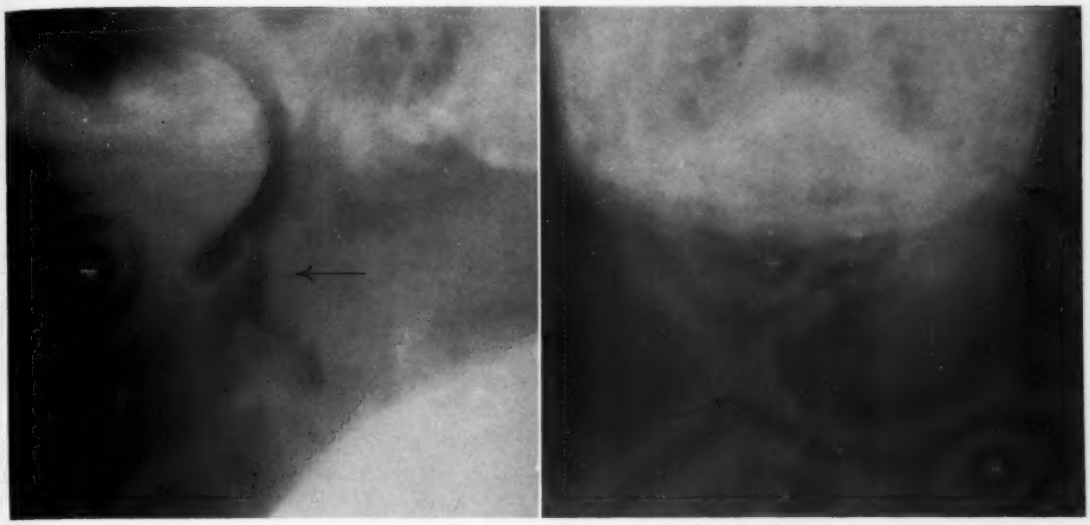

Fig. 14. Case xi. Carcinoma of the right side of the hypopharynx.

Case x. A forty-three year old white woman with sore throat of six months' duration and pain and diminished auditory acuity of the left ear of three weeks' duration had a squamous cell carcinoma of the left side of the posterior wall of the oropharynx extending up into the nasopharynx. The supervoltage roentgenograms (Fig. 13) before and after a course of irradiation with a tumor dose of 4,700 r in thirty-eight days showed the nasopharyngeal tumor and its shrinkage under therapy.

These roentgenograms showed better detail than did the conventional roentgenograms and also provided information as to the extent of the tumor initially and the response to irradiation subsequently.

Case xi. A fifty-two year old white man with a history of right lateral neck swelling showed a large mass on the right posterolateral wall of the hypopharynx (Fig. 14). In the frontal projection the mass obliterated the pyriform sinus. This was an epidermoid carcinoma.

Case xii. A forty-six year old white man had a history of hoarseness of six months' duration. The supervoltage roentgenograms of the neck (Fig. 15) showed a fixed tumor of the left vocal cord which extended laterally into the pyriform sinus and inferiorly into the subglottic zone. The mobility of the right vocal cord was demonstrated in the roentgenograms made during breathing, phonation, and while holding the breath.

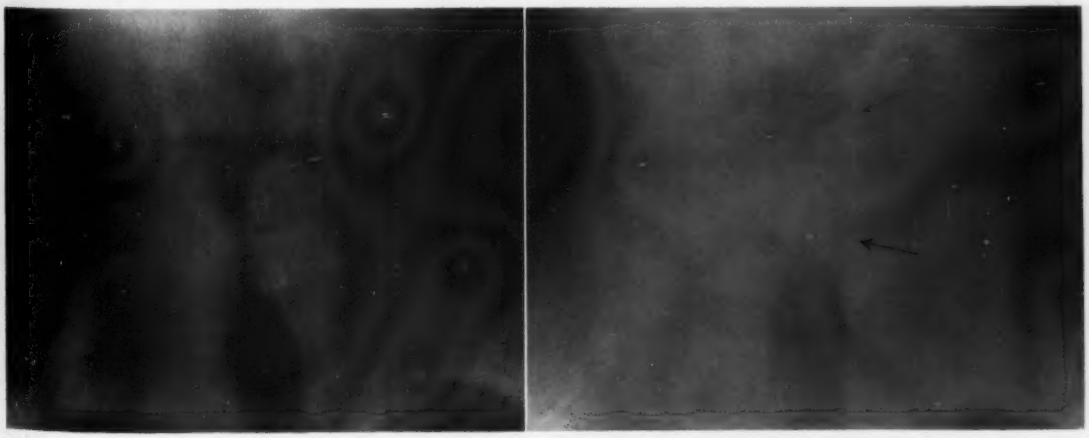

Fig. 15. Case xii. Carcinoma of the left vocal cord.

FIG. 16. Case XIII. Retroperitoneal pneumogram showing enlarged retroperitoneal lymph nodes of Hodgkin's disease in the left upper quadrant.

AIR CONTRAST EXAMINATION

Our experience with supervoltage roentgenography in those parts of the body where air is introduced to provide contrast is limited. The examples shown here—a retroperitoneal pneumogram and a cervical myelogram—are intended to illustrate its potentialities rather than to present convincing evidence of superiority over other methods of roentgen examination.

CASE XIII. A twenty-one year old white man with proved Hodgkin's disease had an epigastric mass not clearly delineated by the barium enema or the upper gastrointestinal series. The retroperitoneal air study following the presacral injection of 1,000 cc. of oxygen revealed a lobulated mass of retroperitoneal lymph nodes in the left upper quadrant.

The supervoltage roentgenogram (Fig. 16) showed more pronounced air-tissue contrast and qualitative differences in tissue density than were discernible in the conventional roentgenograms. However, our experience is not sufficient to permit the statement that this would always be true.

CASE XIV. A thirty-six year old white woman with vague neurologic complaints referable to the cervical cord and suggestive of syringomyelia had a cervical air myelogram with films exposed by the supervoltage technique (Fig. 17). The resulting study was normal, although this conclusion was considered significant. The important structures demonstrated included the cervical cord, its junction with the medulla, and the cisterna magna, the clarity of which was enhanced by the faintness of the shadows of overlying bone.

The advantages of air over opaque contrast material in this region are readily apparent. Davies,[2] in studying the effect of unabsorbed contrast media on the central nervous system after myelography, found the incidence of persistent significant symptoms to be 12 per cent in a series of 119 patients and urged restraint in the performance of this procedure. While air as a contrast medium would be far less likely to produce significant sequelae, air myelograms with conventional exposure are difficult to interpret.[7] It would seem that the supervoltage technique offers distinct advantages in cervical myelography, but additional experience needs to be accumulated.

It is obvious that there is room for considerably more knowledge in the clinical application of supervoltage roentgenography than has been assembled up to this point. Certain shadows on the films remain unidentified. The indications and limitations of this technique are not sharply defined and require further study.

DIAGNOSTIC SUPERVOLTAGE ROENTGENOGRAPHY IN RADIATION THERAPY

Roentgen therapy machines have been used for many years for roentgenographic evaluation of beam direction and field localization. Generally, the films exposed in this way have not been outstanding examples of technical excellence, although possibly they were adequate for their intended purpose. It is logical to believe, as was actually shown in some of the case descriptions, that improvement in the quality of these films would provide more information as to the physical aspects of the plan of irradiation by giving a better correlation with the location and extent of a particular

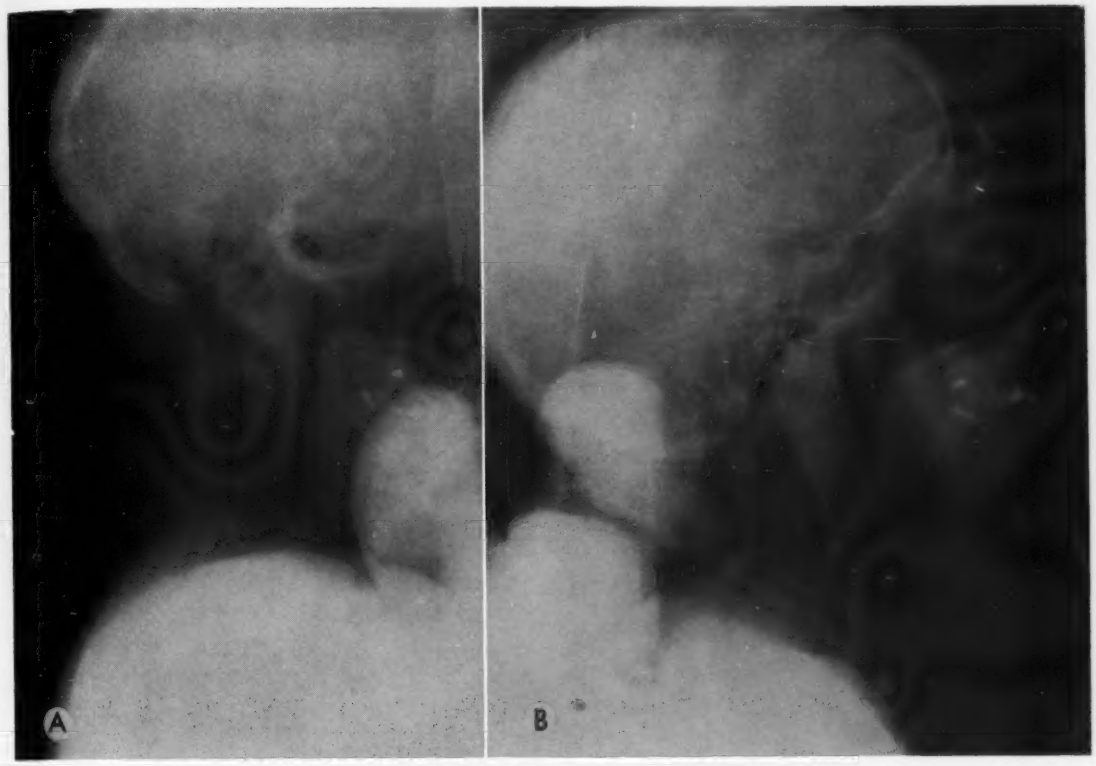

FIG. 17. Case XIV. Normal cervical air myelogram. Lateral decubitus views with patient prone (*A*) and supine (*B*).

tumor. Furthermore, serial studies afford a readily available means to evaluate the effects of irradiation on the tumor being treated. Although this article is limited to experiences with the 1,000 kv. peak roentgen therapy apparatus, it might be stated here, parenthetically, that we have made roentgenograms of reasonably good quality with our 200 kv. peak therapy machine, using the same film and the special cassettes of the supervoltage technique. The clarity of detail is not equal to that seen in the supervoltage films, but the possibilities for the use of this lower quality of radiation are promising.

SUMMARY

Practical experiences in roentgen diagnosis using a 1,000 kv. peak resonant transformer therapy unit have been described.

This technique permits the visualization of air-containing structures in greater detail than do conventional techniques. The lungs, components of the mediastinum, pharynx, and larynx can be more clearly outlined, and abnormalities of these parts might thus be detected at an earlier stage and demonstrated with greater clarity than would be possible with conventional roentgenograms.

The possibility of showing early lesions of the left auricle and the thoracic aorta without the use of intravascular contrast media was raised. There are indications that diagnostic accuracy might be improved in those fields where air is introduced to provide air-tissue contrast, such as cervical myelography and retroperitoneal pneumography.

The use of supervoltage roentgenography to enhance conventional methods of roentgen diagnosis has been shown to be technically practical and clinically worthwhile.

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ROENTGEN DIAGNOSIS OF PERICARDIAL EFFUSION*

NEW ANGIOCARDIOGRAPHIC OBSERVATIONS

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WITHIN two years following the discovery of roentgen rays, Dr. Francis Williams[19] had already studied the roentgen aspects of pericardial effusion. He found that blood, water and soft tissue were of the same density and that it was impossible to differentiate them by usual roentgenographic means. It was not until the heart could be opacified separately from its surrounding fluid by contrast material as in angiocardiography, visualization of the opaque catheter in the cardiac chambers during cardiac catheterization, or by air in pneumopericardium that the differential diagnosis of pericardial effusion from enlarged and dilated heart became established.

The size of the cardiac silhouette in pericarditis with effusion depends upon the amount of fluid and on the bulk of the heart. The most reliable and earliest sign of pericardial effusion is enlargement of the cardiac silhouette in serial roentgenograms. Normally, the pericardial sac contains 15 to 30 cc. of fluid. It has been estimated that at least 250 cc. of fluid is necessary to cause a recognizable change in the cardiac shadow.[16] Fluid first accumulates in the most dependent portion of the pericardium and then retrosternally (the area of least resistance).[21] The pyriform (water bottle) shape in the erect position may become more globular in the horizontal position due to gravitational effect. The length of the cardiac silhouette increases more rapidly than its transverse diameter. Straightening of the normal contours, especially the left, aids in the diagnosis of pericardial effusion.[2,6,16] The superior mediastinum on the right may, in some instances, such as in cardiac tamponade, be widened by an enlarged superior vena cava; usually, cardiac pulsations are diminished or absent. Change in size of the heart does not occur with the Müller or Valsalva maneuvers in pericardial effusions, in contradistinction to dilated hearts.[1] Also, the right cardiohepatic angle often becomes more acute with massive effusions.

These roentgen signs, while helpful, rarely permit the definitive diagnosis of pericardial effusions. This is well summarized by Kern *et al.*[10] in their discussion of the pitfalls in the roentgen diagnosis of pericardial effusion in myxedema. Angiocardiography, on the other hand, conclusively differentiates between a pericardial effusion and cardiac dilatation.[11,20] Opacification of the cardiac chambers establishes their size. From this, estimation of the size of the walls of the chambers may be made. Normally, the wall of the right atrium measures between 1–3 mm.; the right ventricle 3–5 mm.; and the left ventricle 10 mm. Hypertrophied ventricles rarely exceed 20 mm. Accordingly, a soft tissue density greater than the above, especially if it surrounds the heart in frontal view, is most likely to be due to pericardial fluid. Pericardial thickening due to chronic pericarditis is usually of moderate degree (5 mm.); whereas, pericardial fluids may measure as much as 40 mm.[5,20]

Angiocardiography in the lateral projection in pericardial effusions has not been previously described. New studies herein reported clearly demonstrate the anterior, lateral and inferior position of the pericardial fluid in relation to the heart. Superiorly, the aorta, and posteroinferiorly, the inferior vena cava and pulmonary veins are fixed by pericardial reflections. These apparently anchor the heart in the posterior position.

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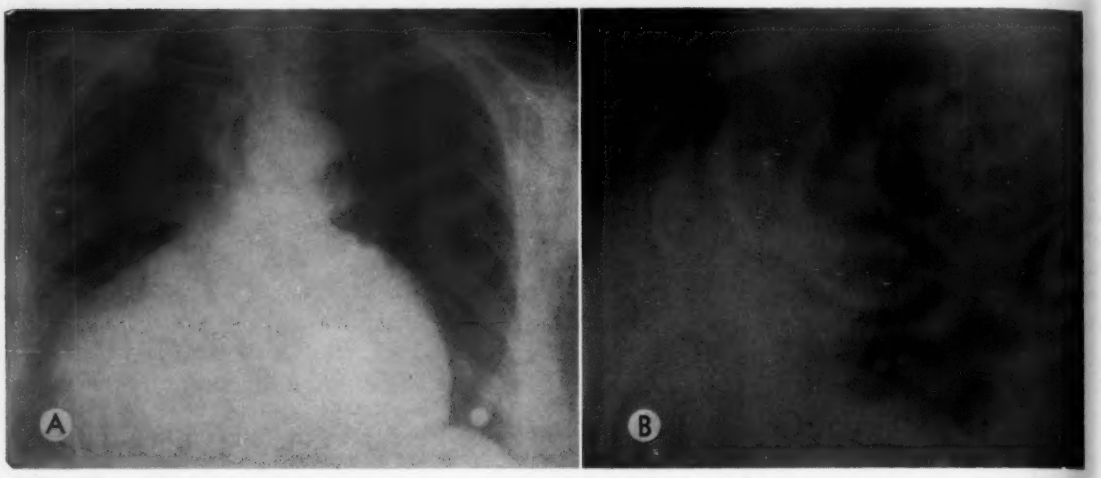

FIG. 1. Case I. Massive chronic idiopathic pericardial effusion in a sixty-eight year old woman. (*A*) Frontal roentgenogram shows a huge cardiac silhouette, especially towards the right. (Calcifications of the left base probably represent old tuberculous lesions.) (*B*) Left lateral roentgenogram shows rounding of the sternum by a huge retrosternally placed cardiac silhouette.

Thirty patients with pericardial effusion studied by angiocardiography form the basis of this report. They represent a selected series because angiocardiography was utilized only in those patients where pericardial fluid was not clearly recognized and represented a problem in diagnosis. Chiefly, the differential diagnoses were a dilated or an enlarged heart, a mediastinal tumor or a pericardial tumor.

REPORT OF ILLUSTRATIVE CASES

CASE I. A sixty-eight year old housewife (N.Y.H. No. 217757) was admitted on December 5, 1951 complaining of generalized edema. Ankle edema had been present for many years due to arteriosclerotic heart disease. Two weeks before admission, a sudden pain in the right axilla occurred; four days later, generalized edema became evident. On physical examination, the blood pressure was 155/75 mm. Hg; the venous pressure was 50 mm. saline. There was pitting edema of ankles and back. Rales were present at the lung bases and the heart sounds were faint. A systolic (grade 2) murmur was heard at the base. The area of cardiac dullness was widened. The laboratory data were normal except for the electrocardiogram which showed low amplitude. The chest roentgenograms (Fig. 1, *A* and *B*) revealed massive enlargement of the cardiac silhouette in all diameters. In frontal view, the right border of the cardiac silhouette almost reached the right lateral chest wall.

Angiocardiography on December 13, 1951, (Fig. 1, *C*, *D*, *E* and *F*) clearly defined a massive pericardial effusion with asymmetric accumulation of fluid anteriorly. The fluid was also lateral and inferior to the heart, which was displaced posteriorly. Thoracotomy by Dr. Cranston W. Holman on December 17, 1951 disclosed a large nonloculated pericardial effusion. The fluid was cloudy and sterile. Postoperatively the patient made an uneventful recovery and the cardiac contour became normal (Fig. 1*G*).

CASE II. A sixty-six year old housewife (N.Y.H. No. 715356) was referred by Dr. Elliot Hochstein on July 15, 1955 because of weakness and chest pain of six weeks' duration. She had been in good health until the onset of constricting chest pain, six weeks before admission. Five weeks earlier she had been admitted to another hospital for heart failure and atrial fibrillation. Prior to admission to The New York Hospital, retrosternal and precordial pain associated with weakness was present. Physical examination showed distended neck veins and scattered wheezes throughout both lung fields. The heart was enlarged to percussion and the sounds were faint; the rhythm was regular. The liver was slightly enlarged. The blood pressure was 124/74 mm. Hg, and the venous pressure was 135 mm.

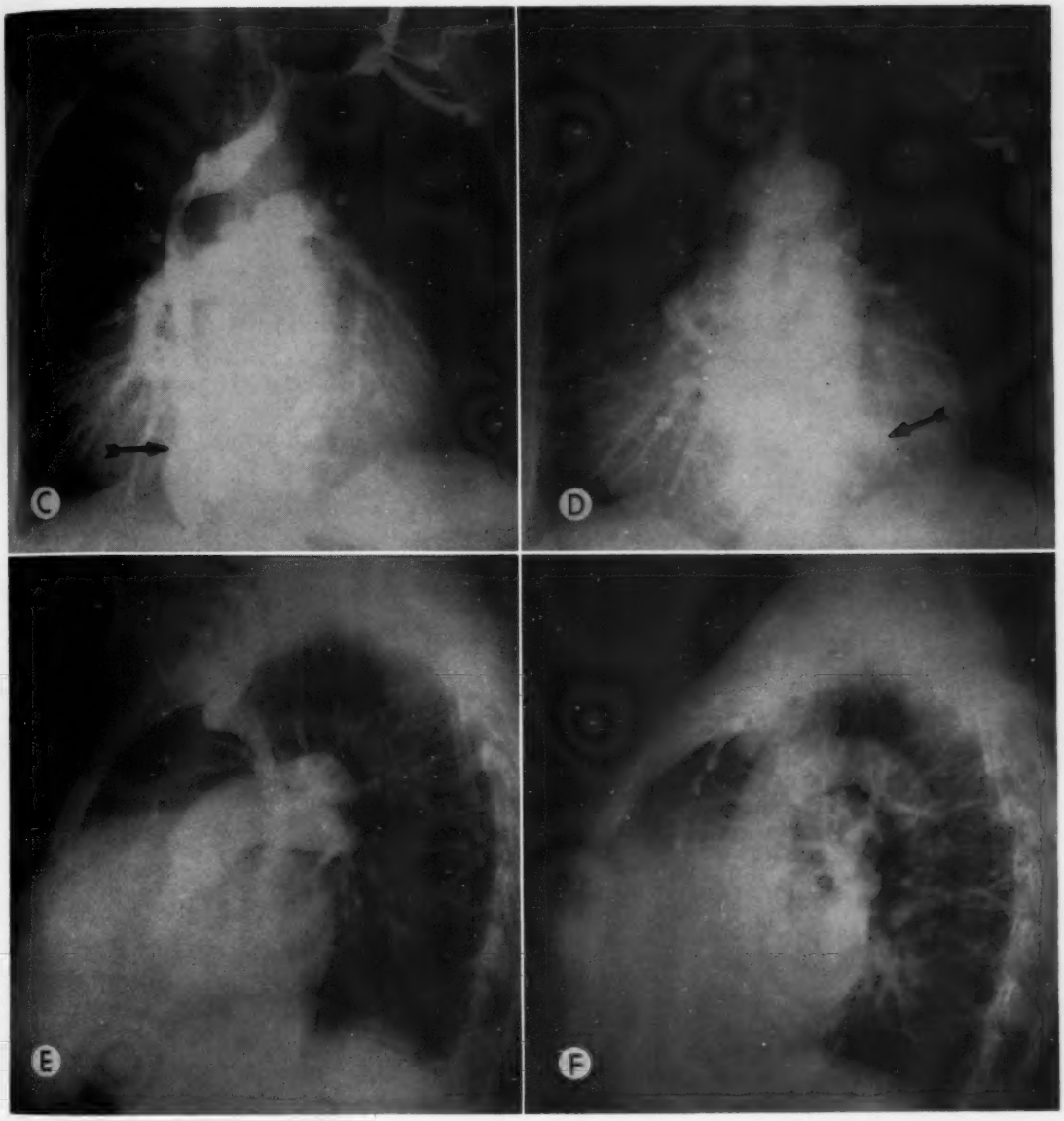

Fig. 1. Case 1. (*C*) Frontal angiocardiogram shows opacification of the normal left subclavian vein, superior vena cava, right atrium, inferior vena cava, right ventricle, pulmonary artery and its branches. Pericardial fluid is seen beyond the right atrium (arrow points to lateral border of the right atrium). (*D*) Frontal angiocardiogram reveals the opacified left heart structures (the pulmonary veins, left atrium, left ventricle and aorta). Arrow points to left ventricular cavity (in systole); beyond, is pericardial fluid. (*E*) Lateral angiocardiogram shows the right heart structures filled with contrast material. Note that the pericardial fluid is anterior and below the right ventricle. (*F*) Lateral angiocardiogram shows the opacified left heart structures. Note that the left atrium is the most posterior chamber within the pericardial sac. Note too, that fluid is present anteriorly and below the heart but not posteriorly.

saline. The laboratory findings were normal except for the electrocardiogram which showed low amplitude.

The chest roentgenograms (Fig. 2, *A* and *B*) showed massive enlargement of the cardiac silhouette in all diameters, chiefly toward the left lateral chest wall and retrosternally. Angiocardiographic examination on July 12, 1955 disclosed massive pericardial effusion with displacement of the heart posteriorly and

FIG. 1. Case I. (*G*) The normal (postoperative) heart.

slightly to the right (Fig. 2, *C*, *D* and *E*).

Thoracotomy by Dr. Cranston W. Holman on July 26, 1955 revealed a markedly thickened and distended nonloculated pericardium containing a large quantity of serosanguineous fluid. The epicardium was shaggy; the pericardial fluid was sterile. Biopsies of the pericardium showed nonspecific changes. The patient was discharged after an uneventful recovery.

CASE III. A thirty-six year old housewife (N.Y.H. No. 656473) was admitted on May 14, 1953 with complaint of left chest pain of twelve days' duration. Two years before admission she had had a febrile illness with pharyngitis and chest pain and after having been admitted to another hospital, a pericardial effusion was found. Seven weeks prior to entry, after another febrile period, the pericardial fluid recurred; 250 cc. serosanguineous fluid was obtained on tapping. On examination, the temperature was 38.3° C., the pulse 120, and the blood pressure 120/90 mm. Hg. The venous pressure was 90 mm. saline. The area of cardiac dullness was increased; the apex of the heart was not seen or felt. The heart sounds were distant and a systolic (grade 2) murmur was heard over the aortic area; a pericardial friction rub was also present over the entire precordium.

Laboratory data revealed a leukocyte count of 14,000; the sedimentation rate was also elevated. The electrocardiogram showed low amplitude and changes due to pericarditis. The chest roentgenogram (Fig. 3*A*) disclosed enlargement of the cardiac silhouette, especially towards the right. The angiocardiograms (Fig. 3, *B* and *C*) demonstrated a large pericardial effusion. The patient was treated conservatively without pericardial tapping and made a complete recovery.

CASE IV. A twenty-two year old woman (N.Y.H. No. 617516) was admitted to another hospital on November 18, 1951 with a history of increasing chest pain and choking sensations of two months' duration. The patient was found to have low grade fever, tachycardia and an increased sedimentation rate. The electrocardiogram showed inverted T waves in most of the leads. Because of an enlarged cardiac shadow the patient was referred to The New York Hospital on January 15, 1952 for angiocardiography. Angiocardiograms showed a pericardial effusion (Fig. 4, *A*, *B*, *C* and *D*). Subsequently, information from the referring hospital disclosed that the patient died of tuberculous meningitis on March 18, 1953.

CASE V. A fifty-six year old woman (N.Y.H. No. 668043) was first admitted to another hospital on September 14, 1953 with the chief complaint of hemoptysis of one week's duration. The past history revealed that the patient had had a left radical mastectomy in 1933, twenty years earlier, which was followed by a course of irradiation (dosage unknown) over a five year period. In 1948, surgical excision of an ulcer of the left chest wall was made; grossly and microscopically, radiation necrosis was found. In 1951, the patient was rehospitalized because of cardiac failure and responded to digitalis therapy.

The examination in September, 1953 showed the heart to be enlarged; a left pleural effusion also was present. The blood pressure was 110/60 mm. Hg; the venous pressure, 280 mm. saline; the circulation time, 23 seconds. The liver and spleen were enlarged and there was ankle edema. The electrocardiogram showed myocardial disease. Roentgenoscopy of the chest revealed a large left pleural effusion. There was also enlargement of the cardiac shadow with diminished pulsations. Left thoracentesis yielded 750 cc. clear yellow fluid. Microscopically the fluid contained lymphocytes; the culture was sterile. Forty-five minutes following the thoracentesis the patient had acute pul-

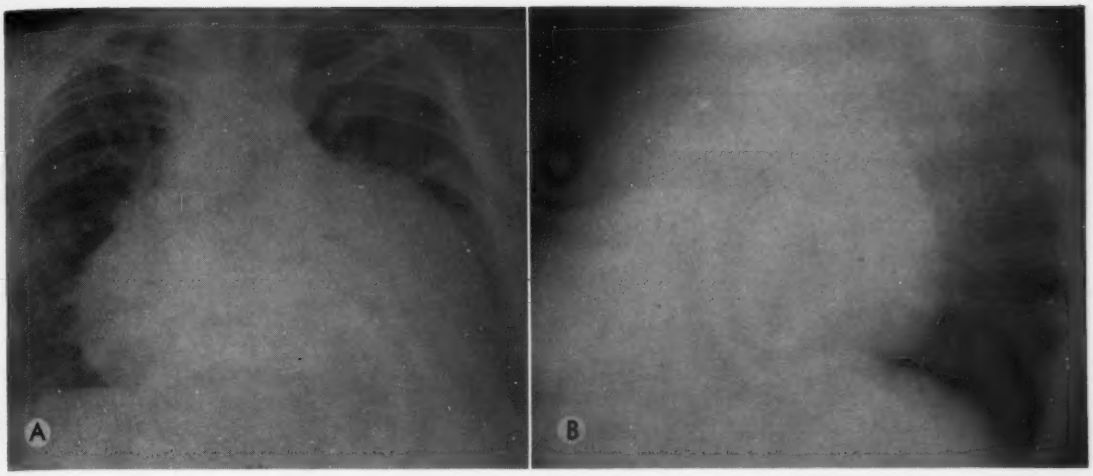

FIG. 2. Case II. Massive idiopathic serosanguineous pericardial effusion in a sixty-six year old woman. (*A*) Frontal teleoroentgenogram reveals a massive cardiac silhouette that almost reaches the edge of the left lateral chest. (*B*) Lateral roentgenogram shows filling of the entire retrosternal space.

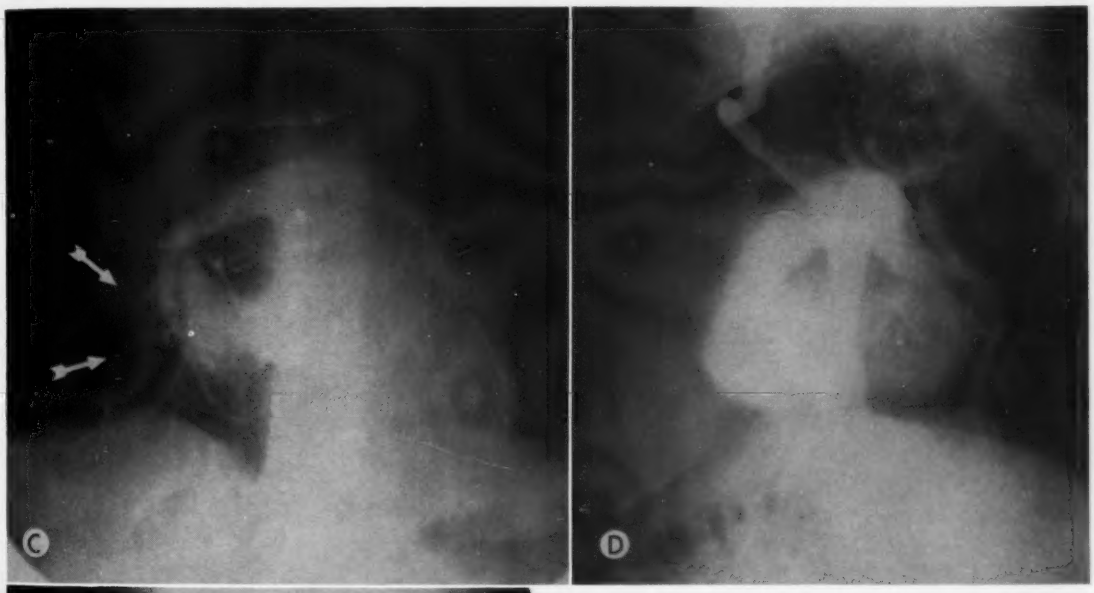

FIG. 2. Case II. (*C*) Frontal angiocardiogram shows opacification of a markedly displaced superior vena cava to the right. The right atrium, ventricle and pulmonary artery are opacified and are normal in size and configuration. The arrows point to the right lateral border of the cardiac silhouette. Note the huge amount of infracardiac pericardial fluid. (*D*) Lateral right heart angiocardiogram reveals the retrosternal and infracardiac location of the pericardial fluid. (*E*) Lateral left heart angiocardiogram shows the posterior border forming position of the left atrium. Again note the retrosternal and infracardiac location of the pericardial effusion.

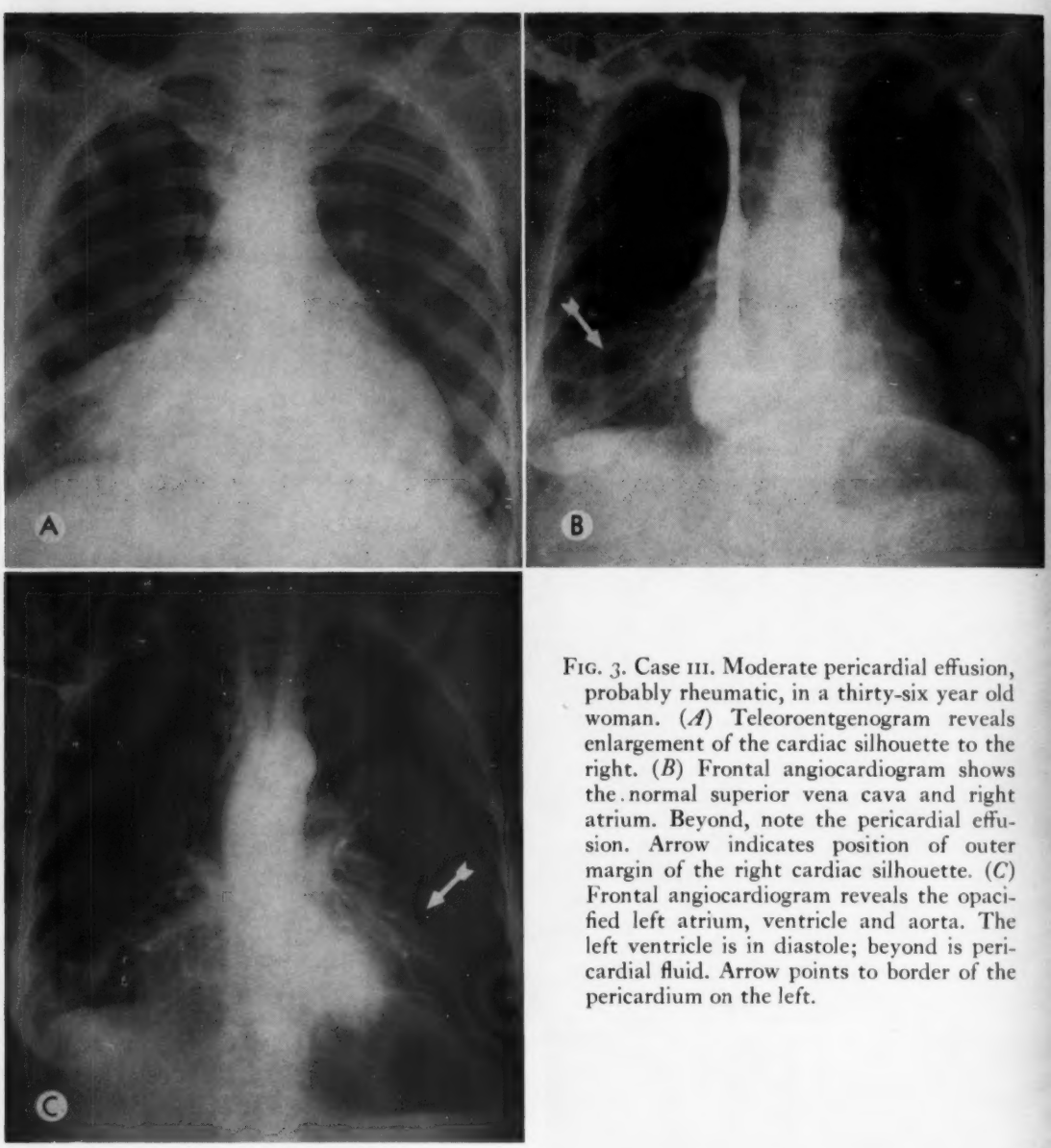

FIG. 3. Case III. Moderate pericardial effusion, probably rheumatic, in a thirty-six year old woman. (*A*) Teleoroentgenogram reveals enlargement of the cardiac silhouette to the right. (*B*) Frontal angiocardiogram shows the normal superior vena cava and right atrium. Beyond, note the pericardial effusion. Arrow indicates position of outer margin of the right cardiac silhouette. (*C*) Frontal angiocardiogram reveals the opacified left atrium, ventricle and aorta. The left ventricle is in diastole; beyond is pericardial fluid. Arrow points to border of the pericardium on the left.

monary edema but responded to emergency treatment which included redigitalization.

The chest roentgenograms, following the thoracentesis, showed the absence of the left breast, a large globular appearing heart, a moderate left pleural effusion, and parenchymal fibrosis in the left perihilar area (Fig. 5, *A* and *B*). The patient was then referred to The New York Hospital for angiocardiographic study.

The frontal and lateral angiocardiograms (Fig. 5, *C*, *D*, *E* and *F*), made October 8, 1953, showed the cardiac chambers to be of normal size. A large pericardial effusion accounted for the enlarged heart silhouette. The left pulmonary artery, however, appeared to be narrowed beginning 4 cm. from its origin. The vascularity of the left lung field was markedly decreased. Five hours following angiocardiography sudden nausea developed and was soon followed by death. At autopsy, the left lung was adherent to the chest wall and 500 cc. of straw colored fluid was in the left pleural cavity. Microscopically, there was fibrosis of the alveolar septa of the left lung with intimal fibrosis and

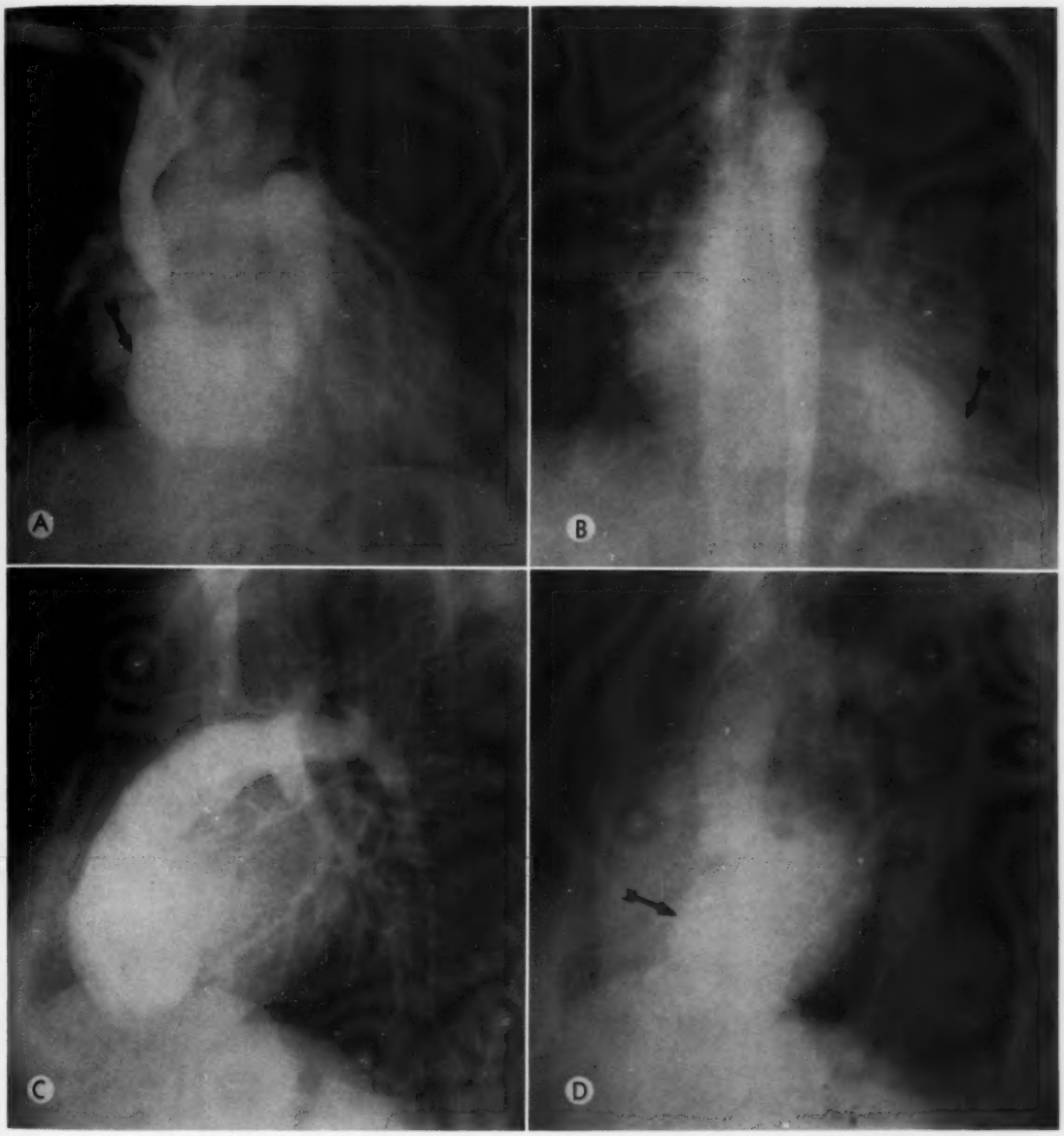

Fig. 4. Case iv. Tuberculous pericardial effusion in a twenty-two year old woman. (*A*) Frontal angiocardiogram reveals a slightly laterally displaced superior vena cava. The right atrium, ventricle, pulmonary artery and branches are opacified. Note the moderate pericardial effusion on the right adjacent to the right atrium (arrow). (*B*) The opacified left ventricle (arrow) is also surrounded by pericardial fluid. (*C*) Lateral right heart angiocardiogram shows only a small amount of pericardial fluid retrosternally and infracardially. (*D*) Lateral left heart angiocardiogram also reveals the posterior border forming position of the left atrium. Arrow points to anterior border of the left ventricle.

narrowing of the lumina of the medium sized arteries. In marked contrast was a normal right lung. The pericardial sac contained 500 cc. of straw colored fluid. The anterior surface of the pericardium was adherent to the posterior surface of the sternum and chest wall. The heart was small and the chambers were normal in size. Microscopically, there was fibrosis of the parietal pericardium which was interpreted as being secondary to radiation.

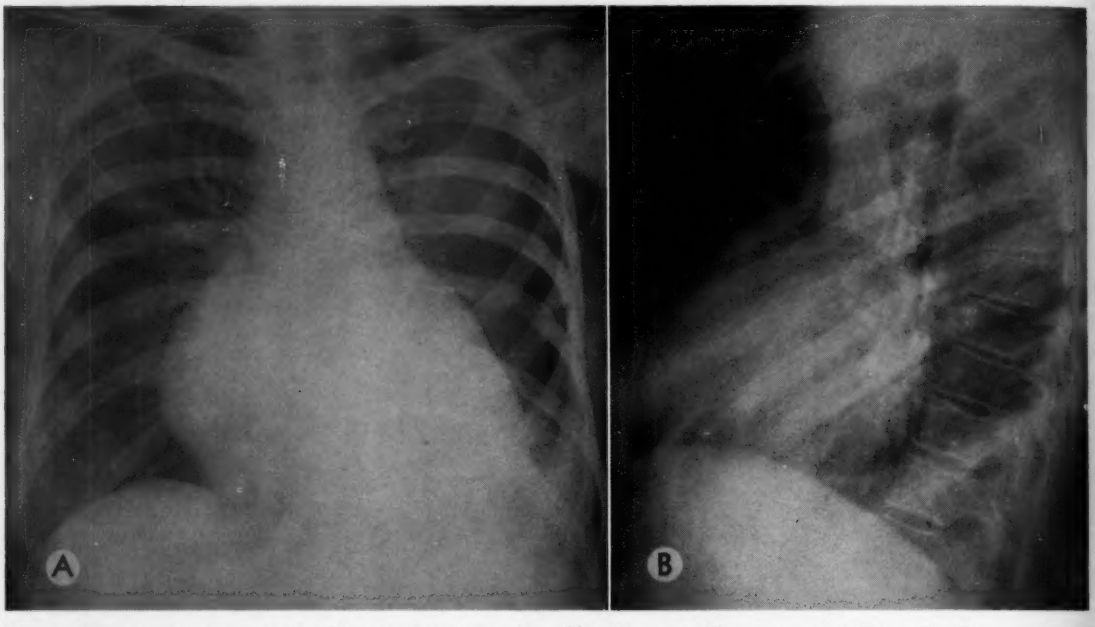

FIG. 5. Case v. Radiation pericarditis with effusion in a fifty-six year old woman. (*A*) Frontal teleoroentgenogram shows an enlarged cardiac silhouette, absence of left breast and left pleural effusion. (*B*) Lateral teleoroentgenogram reveals the retrosternal position of the enlarged cardiac silhouette. There is also a left pleural effusion.

CASE VI. A sixty-three year old housewife (N.Y.H. No. 532741) was admitted on January 19, 1950 complaining of dyspnea on exertion. A year prior to admission, although the patient was asymptomatic, an enlarged cardiac silhouette was seen. Also the blood pressure was elevated (184/100). Six months prior to admission the enlarged heart silhouette was again noted in the roentgenogram and angiocardiography was advised for diagnosis. This disclosed massive pericardial effusion. On examination the patient appeared well. Cardiac dullness extended along the left chest and beyond the axilla. The heart sounds were distant and there were no murmurs. Roentgenograms of the chest (Fig. 6, *A* and *B*) revealed massive enlargement of the cardiac silhouette. The lung fields were clear. Angiocardiographic studies disclosed massive pericardial effusion. Pericardial tap yielded 1,000 cc. cloudy yellow fluid which was sterile. Subsequently, hemorrhagic pericardial fluid recurred and there was also a left hemothorax. Many pericardial and thoracic paracenteses were required over a five month period. Finally, recovery was complete and, when last seen in the clinic in 1954, the patient was well.

DISCUSSION

Angiocardiography in frontal view readily establishes the diagnosis of pericardial effusion by showing the heart surrounded by fluid (Fig. 1, *C* and *D;* 2 *C;* 3, *B* and *C;* 4, *A* and *B;* and 5, *C* and *D*). In the lateral view, the pericardial fluid is anterior (retrosternally) and inferior to the heart chambers (Fig. 1, *E* and *F;* 2, *D* and *E;* 4, *C* and *D;* and 5, *E* and *F*). Golden[7] in 1950, in unpublished data, called attention to the importance of the lateral view in pericardial effusions. He also pointed out that fluid reaccumulated retrosternally because it was the space of least resistance.[8] Our studies confirm Golden's findings that fluid regularly accumulates retrosternally in pericardial effusions. Our studies also reveal that early in pericardial effusions, or with small effusions, the fluid first accumulates in the most dependent part of the pericardium.[21] It then extends anteriorly and is recognized by alteration (straightening) of the cardiac silhouette, especially the left

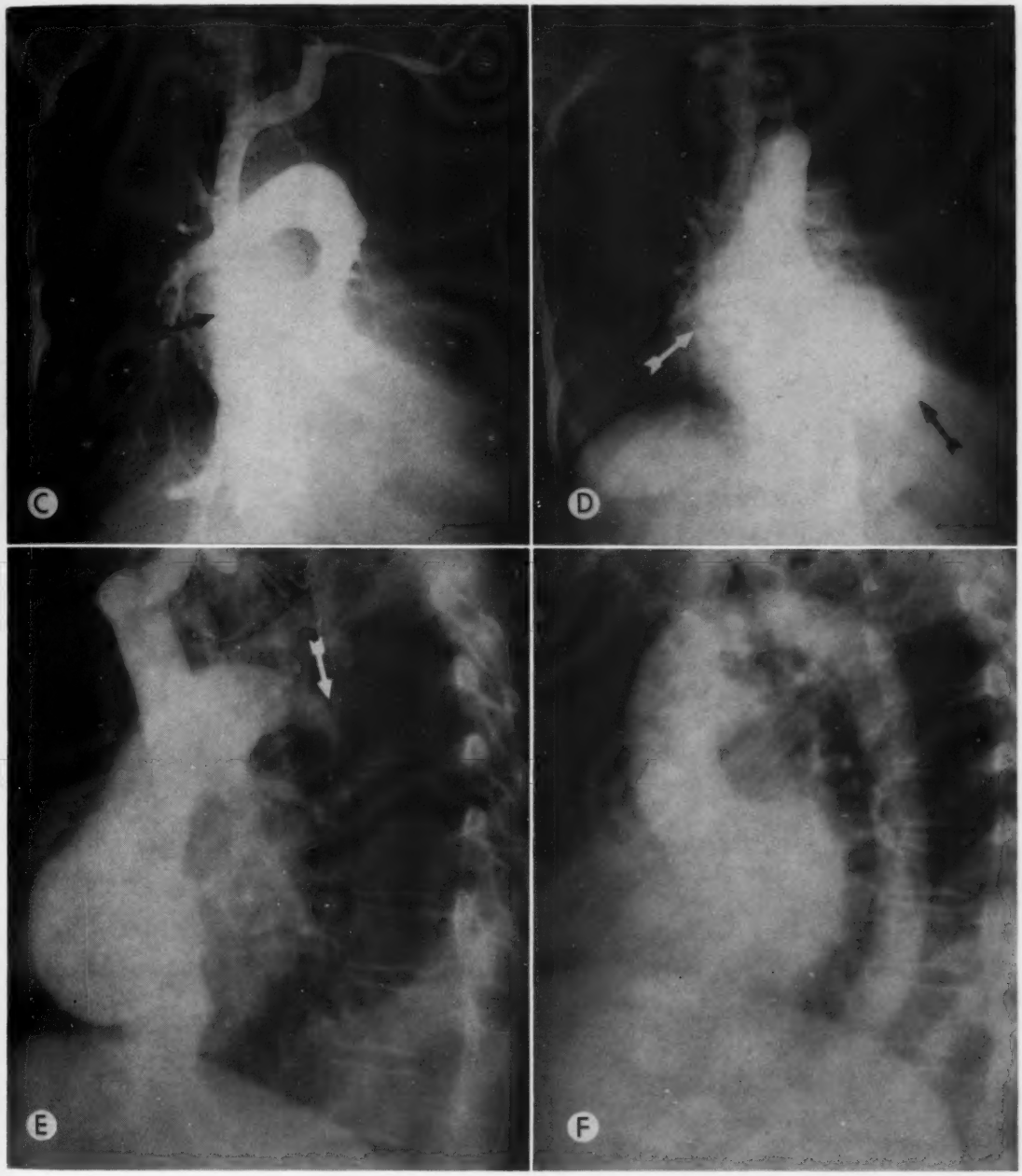

Fig. 5. Case v. (*C*) Frontal angiocardiogram shows the opacified normal left subclavian and innominate veins and superior vena cava. The right atrium (arrow) is surrounded by fluid. The right pulmonary artery appears intact; the left pulmonary artery is ill-defined. (*D*) Frontal left heart angiocardiogram shows fluid beyond the left ventricle (arrow). Arrow on the right, points to the opacified left atrium. (*E*) Lateral angiocardiogram shows the retrosternal pericardial effusion. The left pulmonary artery is markedly narrowed (arrow). (*F*) Lateral angiocardiogram also shows the posterior border forming position of the left atrium due to backward displacement of the heart by the anteriorly placed pericardial fluid.

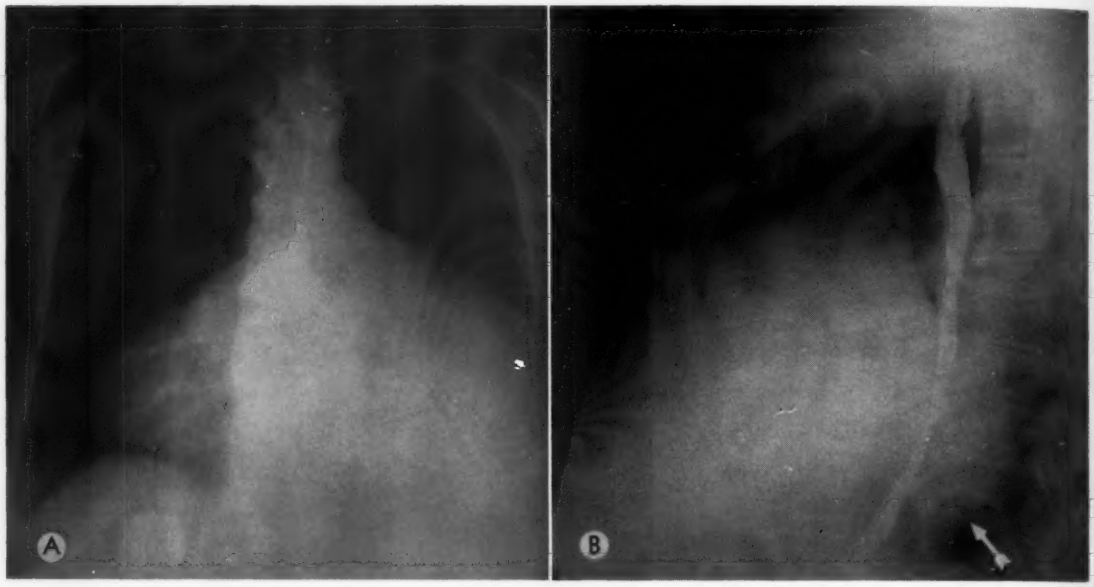

FIG. 6. Case VI. Massive chronic idiopathic pericardial effusion in a sixty-three year old woman. (*A*) Frontal teleoroentgenogram shows a huge cardiac silhouette, reaching the left lateral chest wall. (*B*) Lateral esophagram demonstrates the posterior position of cardiac structures; beyond (arrow) is pericardial fluid in a distended lateral pericardial pouch.

border. Pericardial effusions apparently never accumulate behind the heart. However, massive pericardial effusions distend the lateral pericardial pouches or recesses and may extend far backwards (Fig. 6*B*). Indeed, inflated water wings (of another era) when held against the chest for swimming assume the same position. This is well illustrated in Figure 6*B* which shows that the esophagus lies against the posteriorly displaced cardiac chambers, and beyond, there is another shadow, the distended pericardial pouch. Lukas[12] has suggested that fluid is squeezed from the posterior pericardium by the inflated lungs. Golden,[8] however, believes that pericardial fluid lies anteriorly because there is no resistance to its accumulation in this area.

The concept that backward displacement of cardiac chambers or the distended pericardial pouches causes compression of the lung helps to understand the mechanism of Ewart's sign.[18] Ewart's sign is an area of dullness, increased fremitus and egophony that occurs in an area of variable size at the inferior angles of the scapula (most often, the left) with pericardial effusions. It is apparently nonspecific and has also been described with cardiac enlargement, especially of the left ventricle.[4]

The ages of the 30 patients with pericardial effusion herein reported varied from fourteen to sixty-eight years. Females predominated, 21 as compared to 9 males. The etiology of the pericardial effusion was idiopathic in 17 cases; tuberculous in 4; rheumatic, 4; myxedema, 2; metastatic, 1; lupus erythematosus, 1; and in 1 (Case V), pericardial effusion was due to the late effects of irradiation. Only 1 other case of pericardial effusion following radiation therapy is recorded in the literature.[3] Case V is also of interest because it is the only death in a consecutive series of 3,100 patients studied angiocardiographically at The New York Hospital. The patient was seriously ill as attested to by the earlier sudden heart failure that followed thoracic paracentesis.

Two patients in the series had massive idiopathic serosanguineous pericardial effusions. The occurrence of blood in the pericardial fluid in still another case recently studied with myxedema suggests that hem-

orrhage may be caused by the severe mechanical stretching and tearing of the pericardial capillaries by massive pericardial accumulations. Since hemorrhage may thus be spontaneously produced, search for neoplastic sites or myocardial infarction and other causes of hemopericardium, need, therefore, not be prolonged. Acute symptoms of pericardial tamponade also followed hemorrhage in 3 cases. Therefore, when sudden discomfort develops in patients with chronic pericardial effusions, bleeding into the pericardium should be suspected. The danger of overlooking cardiac tamponade in so-called benign idiopathic pericardial effusions has also been recently stressed.[14] The dangers of needling dilated enlarged hearts and producing coronary and/or myocardial laceration is generally known. It follows, therefore, that diagnosis of pericardial effusion is important. Despite the single fatality in our series, angiocardiography for diagnosis of pericardial effusion is recommended and is safer than diagnostic pericardial paracentesis. Recently, several reports recommending surgical treatment of pericardial effusions and biopsy of the pericardium for diagnosis have appeared in the literature.[9,13,15,17] If such surgery is contemplated, the preoperative diagnosis by angiocardiography is particularly important.

SUMMARY AND CONCLUSIONS

Angiocardiography was done in 30 patients with pericardial effusion to differentiate them from large dilated hearts and mediastinal tumors. In every instance, the characteristic feature of pericardial effusion, a heart surrounded by fluid, was demonstrated in frontal view. In the lateral projection, however, the pericardial fluid was always anterior, retrosternal, and infracardiac causing backward displacement of the heart.

It seems that small amounts of pericardial fluid first accumulate below the heart. The fluid extends anteriorly and then appears along the lateral borders of the heart with consequent "straightening." When massive pericardial effusions occur, the lateral pericardial recesses behave very much like water wings and present laterally. These lateral pouches may fill asymmetrically simulating pericardial or mediastinal masses. It is recommended, in order to avoid traversing the lung, that the anterior or infracardiac approach be used for pericardial paracentesis.

Angiocardiography is recommended for diagnosis of pericardial effusions in problem cases. This method is preferred to diagnostic pericardial paracentesis because enlarged and dilated hearts are easily lacerated. The increasing use of surgery for treatment and biopsy of the pericardium in pericardial effusions also makes preoperative diagnosis imperative.

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DIRECT COLOR ROENTGENOGRAPHY

THE THEORY AND FACTS OF COLOR ROENTGENOGRAPHY

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AFTER Donovan[9] startled the Medical Society of his native Ireland with the first glimpse of simulated color roentgenography in March, 1949, Pirkey, Parker, and Shook[24] presented an excellent simulated color process in December, 1950. A similar Flexichrome color scheme was adapted after the latter workers and was presented as a modified process employing commercially available Matrix film for direct color transparencies.

This method was reported in an article entitled "Simulated Color Roentgenography."[10] Before that paper was presented for publication, we had already been stimulated by our observations to consider the possibility and feasibility of direct color roentgenography. In fact, a paper was presented to the JOURNAL, in March, 1954, which was accepted for publication, and then withdrawn at the request of the author. Our work had disclosed by mere chance alternate means of color effect, and we asked that the publication of the paper be postponed. The investigations and experiments these past few years have substantiated our theories with crude results that will permit us to discuss some of the facts and theories of color roentgenography.

At the onset, all of our work up to 1951 had been in *simulated* color roentgenography primarily for teaching and correlation of anatomy in the first year of the medical curriculum. The following discussion relates to observations in *direct color roentgenography* as we have formulated our theories and developed our work in accordance with the already established facts.

In the original experimental procedures, it was astonishing to observe the homogeneity of absorption of color in the film emulsion which so accurately recorded and maintained the contrast qualities of the original roentgenograms. This observation in itself indicated the possibilities of direct color roentgenography.

HISTORIC REVIEW

The phenomenon of color change and the chemical effects of roentgen rays are neither new nor entirely unknown. In fact, a study of the literature discloses a wealth of factual information dating back to almost immediately following Röntgen's discovery.

With the discovery in 1895 of the very penetrating roentgen rays that now bears Röntgen's name, the recognition of natural radioactivity by Becquerel in 1896 and the isolation of radium by the Curies in 1898, there was an immediate need for radiation dosimetry. Early in the therapeutic use of irradiation a unit of dose was essential for proper evaluation and specification of quantity.

The problem of radiation measurement was approached by various ingenious devices. The measures which resulted ranged from one extreme to the other and included: a measurement of the electric current used, the penetration method of Benoist, skiameters, ionization methods, photometric methods, and the physicochemical methods.[21] The latter phenomenon which was based upon the chemical effect of roentgen rays resulted in the development of the chromoradiometers, the first dosimeters.

The actual chemical effect of roentgen rays had been known for a long time and was used quite early as a means of measuring dose. The ability of roentgen rays to change the color of many chemicals by altering the atomic structures of these substances had been known since before the turn of the century. It was found that common table salt liberates chlorine and turns yellow from lengthy exposure to roentgen rays. This led G. Holzknecht to

propose a method for quantitative measurement of roentgen-ray intensities, and the first definition of radiation dosage. The discoloration of a fused mixture of HCl and Na_2CO_3 by radiation was used in his dosimeter which was called the "chromoradiometer." The unit, H, was arbitrarily defined as "that amount of radiation, such that 3H gave a light skin reaction." This unit so defined by Holzknecht was never widely adopted or accepted, presumably because the chemical composition of the ingredient salts used was not disclosed for some time after the original publication of the method in 1902.[16]

A similar method of chemical dosage measurement was developed with the use of barium platinocyanide. This substance normally is bright green, and with exposure to roentgen rays its color changes gradually to orange, and then through several shades of brown to a final dark yellow or golden brown hue. The change in color depends upon the amount of energy absorbed by the barium platinocyanide. This method was propounded by Sabouraud and Noiré[25] in 1904 and came into quite general usage. In fact, it is still used to a considerable extent in European countries. The unit of dose was defined as that amount of radiation which changed the color of the small pastille from tint A, a bright green, to Tint B, a dark yellow or golden brown hue. This amount of radiation was the maximum dose which would prevent permanent epilation or recognizable dermatitis. In order to obtain fractional doses Holzknecht arranged a color scale for the various tints between a lower gradation A and an upper gradation B. He divided the total Sabouraud-Noiré dosage into five units and called each "1 H."

It remained for Bordier and Galimard[6] to demonstrate and evolve the explanation that the discoloration of the pastilles such as barium platinocyanide was due to the elimination of the water of crystallization from the chemical. This likewise, could be produced, of course, by heat or even visible light, as well as by irradiation. One of the difficulties in the method was in the inherent absorption discontinuity of both platinum and barium. This discontinuity of absorption unfortunately occurred in the region of the wave lengths used most frequently in therapy. Consequently, the amount of radiation energy and the resultant change of color by the chemical was not proportional to the absorption or exposure of the tissue and the consequent biologic reaction over the range of wave lengths used.[16]

Still another method of dosage measurement using the chemical action of radiation was developed by Freund[11] in 1904. His method made use of the release of free iodine in an iodoform-chloroform solution which was exposed to roentgen radiation. The method specified a 2 per cent iodoform solution with a release of free iodine and a resultant red color which was used as an indicator of dose. This method had its disadvantages principally because of the subjective error in interpreting or determining the exact color hue. Galimard with Bordier modified the original method of Freund by specifying a constant area of surface and the exact volume of the solution which was titrated for the amount of free iodine released. This last method was abandoned because it was shown by Baumeister and Glocker[3] that the amount of iodine precipitated was not proportional to the amount of energy absorbed. Still another dosimetry was proposed by Schwarz[26] involving the precipitation of calomel (Hg_2Cl_2) from a solution of ammonium oxalate and mercuric chloride when exposed to roentgen radiation.

The desire for color was created with the development of photography. Seebeck in 1810 noted that color was reproduced when the color spectrum was exposed on a freshly prepared moist layer of silver chloride. Beaumont[5] states that in 1827 Daguerre noted that his light-sensitive plates reproduced the color of the light to which it was exposed. An associate, Nicéphore Niepec, wrote his brother that Daguerre had registered four out of the seven primary

colors on his photographic plates. Daguerre felt that this phenomenon was not useful and discontinued his experiments in favor of a "more immediate and practical process." It took twenty years to recognize the significance of Daguerre's observations and make practical use of the phenomenon. In 1850 Levi L. Hill announced he had a method for reproducing natural colors in photography. Although there was no confirmation of this process, it was indicated from evidence given by Samuel F. B. Morse that Hill had succeeded in accomplishing color photographs. It is possible that he had encountered the phenomenon of Daguerre noted in 1827.[5]

Interestingly, in France Becquerel[5] had shown great interest in this phenomenon and like a keen scientist investigated thoroughly. He realized that silver chloride could be made in a number of ways, and that these varied emulsions of silver chloride reacted differently to light. A few of his silver chloride preparations reproduced the color to which they were exposed, but a repeat exposure to the same light eliminated the color. There were some silver chloride emulsions which showed no color sensitivity, but turned a violet hue when exposed to any light. Becquerel in 1848 reported to the French Academy of Sciences that "the reproductions of the images of the spectrum and in the camera with natural colors have nothing more than a purely scientific interest, and their practical application can only be dreamed of, because they last only in darkness and gradually change in light."[5]

Perhaps the best known and most accurate of the chemical dosimetry methods was the Sabouraud-Noiré Pastilles. Various so-called *radiometers* of this type evolved, but the one developed by Holzknecht seemed the most suitable. The chief chemical component, barium platinocyanide, was compressed into tablets in the form of half-disks. The radiometer was perfected as an instrument in 1911 by W. Hampson, then Radiographer to the Queen's Hospital for Children. It was first manufactured by Messrs. Newton & Co. of London and called

Fig. 1. The Hampson Radiometer in the compact-like carrying case.

"Dr. Hampson's Roentgen Radiometer."[19] Later this ingenious little device was marketed in this country with improved design modifications by the old Victor X-Ray Co. as the "Hampson Radiometer." As shown in the accompanying illustrations, the entire device was enclosed in a small compact-like protective case (Fig. 1), which contained the entire instrument (Fig. 2). The essential component parts are apparent in the enlargement (Fig. 3) which shows tint 12 of a calibrated comparator-scale arranged around the edge of the instrument. The scale was selectively rotated to the tint corresponding with the exposed pastille which was in place in the slot just above the numeral visible in the scale window. A spare pastille tab was in position below the base of the instrument for illustration. When the pastilles wrapped in light-tight black paper were exposed to roentgen rays for different lengths of time the color changed gradually from a normal bright green to an orange or golden brown tint, or dark yellow. The exposed pastille was then compared to the standard comparator-scale of varying shades which allowed estimates of dose to be judged.

THEORETIC CONSIDERATIONS

At the outset, with the advent of knowl-

FIG. 2. The actual instrument demonstrating its adjustable calibrated comparator-scale and the compressed pastille tabs.

edge and the discovery of roentgen and gamma radiation, it was expected that numerous and extensive chemical effects should result from the effects of penetrating radiation. However, there are very few actual profound chemical changes known.

FIG. 3. An enlargement to demonstrate the essential component parts of the radiometer.

The *photographic effect* is the most outstanding example of chemical effect, although a few oxidation-reduction reactions are known, as well as some examples of condensations of organic compounds. The apparently large number of chemical systems which show sensitivity to ultraviolet exposure are not affected by roentgen radiation. A large number of solutions and colloidal suspensions were thought to be a possible avenue of investigation. Especially since such solutions would provide selected mediums approximating the absorption and scattering characteristics of actual tissue density.[27]

Clark[8] has summarized beautifully the several points of interest in the consideration of the subject of the chemical effects of roentgen radiation and he has listed them as follows: "(1) Pure photochemistry —the mechanism, rate of reaction, and the stability of chemical bonds. (2) Possible therapeutic effects by use and study of chemical changes with irradiation. (3) Discovery of reactions suitable for quantitative or intensity radiation dosimetry."

An addition to this is a possibility and belief that other chemical effects may be discovered which will permit of such sensitive color change and variation as to be effective with the slightest amount of exposure, superficial or penetrating.

Certain photochemical reactions are useful as indicators of roentgen-ray intensity. In reactions where a detectable change such as a precipitation or release of gas is related to direct dosage, calibration in terms of unit exposure is feasible. The precipitation test of Schwarz between mercuric chloride and ammonium oxalate with the formation of calomel is one of the best examples of a chain reaction. The decoloration of methylene blue and other numerous reactions were potential dosimeters for specific exposure determination. The oxidation of ferrous sulfate to ferric sulfate by roentgen exposure has been studied quantitatively, as well as the reduction of potassium nitrate to potassium nitrite. The transformation of oxyhemoglobin to met-

hemoglobin has been observed as another chemical effect of roentgen rays. The flocculation or peptization of certain colloids has been indicated as still another useful chemical reaction of roentgen-ray exposure. Some increase in the activity of certain catalysts has been attributed to the effect of roentgen rays.

In view of all these reports and studies it is obvious that a great research problem challenges us at present, and that an enormous amount of tedious research lies ahead.

FACTS

The actual mechanism of color action of the roentgen rays depends in the first place on the chemical action, which is extremely complex as evident from the wide variety of experimental observations made by numerous workers. The exact chemical reaction is still obscure and inadequately explained. In only a few instances has any adequate theory been substantiated.

The best known reaction, as has been indicated, is the photographic action which occurs when film emulsion is exposed to light or roentgen radiation. Much speculation occurred from the onset and many theories were advanced to explain the observable phenomena and actinic action of the roentgen rays. The complexity of the subject is substantiated by the evidence of present day knowledge and experience.

It is the consensus now that absorption of radiation energy must occur if any chemical effect is to be observed. The photoelectron released by actinic action of roentgen rays is believed responsible. These photoelectrons carry a high initial velocity and easily liberate secondary electrons on impact collision. The released or converted energy of a quantum of roentgen ray in absorption is transferred to the photoelectrons released and coupled with the available potential energy of the ionized atom. These latter atoms then enable chemical reactions to occur because of their altered condition when orbital exchange is created as a result of photoelectron transference. Ionized atoms are capable of chemical reactions as a result of their altered condition of instability.[8]

The mechanism of chemical action is summarized by Clark and diagrammatically illustrated by Figure 115 in his text[8] and reproduced in Glasser's "Medical Physics," p. 1345.[17] The exciting radiation is represented as a photon with the energy hv (where h is Planck's constant and v frequency). This primary photon of radiation collides with an atom which thereby becomes an ion on ejection of a high speed photoelectron. The liberated ion is an altered chemical product from the neutral atom and because of its changed condition is capable of chemical reactions. Clark explains, "the most important particle in obtaining photo-chemical change is not the primary photon, scattered or secondary photons, but the accelerated photo-electron. On impact with an atom or molecule, energy is added so that the electronic configuration in the bombarded particle is altered and excitation or activation occurs. The activated molecule has characteristic instability and sensitivity to chemical reactivity. Change may occur in a molecule only in a single bond; in any case, this activated atom or molecule is then ready for a chemical reaction, impossible or unlikely hitherto in the unexcited state. This energy may be imparted to other atoms and molecules and thus there is a return to the lower energy of the normal state. Quantitative measurements of energies have confirmed the principal mechanism for a few systems."[8,17]

Still another mechanism to be considered is the absorption of roentgen rays by atoms in molecules with conversion into heat. The increase in energy of motion of atoms within molecules results in a local elevation of temperature, although the amount is infinitesimal. The Einstein photoequivalence law is not adhered to in this regard. The roentgen ray quantum is about 10,000 times greater in energy than a light quantum, and yet has only 1,000 times greater chemical effect. The discrepancy is due to scattering of energy as heat. Dependence

on wavelength is determined by the number of absorbed quanta, *i.e.*, the absorbing properties of the photographic plate or film. Roentgen rays differ from ordinary light in their chemical effects in as much as ordinary light only excites atoms by elevating electrons to high energy orbits. Also roentgen rays differ in that they induce chemical reactions by scatter and recoil electrons without fluorescent absorption.[17,18] On the other hand, roentgen rays seem similar to ordinary light in their action on photographic emulsion. There are no known photographic emulsions sensitive to roentgen rays that are not also sensitive to ordinary light rays. The characteristic penetrability of roentgen rays induces an equal distribution of reduced silver grains through the thickness of the film emulsion which light rays cannot produce.

Roentgen rays and light rays are arranged within the electromagnetic spectrum in accordance with their specific wavelengths. Electric waves, radio waves, infrared rays, visible light, ultraviolet light, roentgen rays, and gamma rays of radium all occupy a specific position within the spectrum of electromagnetic radiations. These rays, light and roentgen rays, all have the same characteristics. They are rhythmic, electromagnetic oscillations, or wave motions traveling with the same tremendous speed, and differing only in the length of their waves.

The light waves of the visible spectrum which stimulate the retina are within the band which ranges from about 3,200 to 7,700 Angstrom units, whereas the roentgen ray spectrum extends from 0.06 to 1,020 Angstrom units. The roentgen rays of most importance to the radiologist for diagnostic purposes are those between 0.125 and 0.50. In the roentgen-ray region of the spectrum, the shorter the wavelength of the radiation, the greater is its penetrating power, and the harder the radiation. Therefore, the "quality" of a roentgen-ray beam depends on its wavelength. The hardest rays have the shortest wavelengths. So variables of "hardness" are closely analogous with variables of "color" in a beam of light.

PREMISES

Our "theory of explanation" may be projected at this point and expanded. Radiation from a source of visible light can be separated into its components according to wavelengths by passing it through a glass prism and producing a *spectrum*. It is evident that the spectrum will consist of continuous general radiation superimposed upon by one or more narrow bands of characteristic radiation. The general distribution of energy among the various wavelengths is not obvious; however, the characteristic bands will contain more energy than other wavelength regions. The actual energy distribution can be obtained by spectral analysis.[23]

In the case of visible light, the general radiation can be separated into its components to produce the spectrum by means of the prism or grating. With the roentgen-ray beam it is necessary to use natural crystals as the diffraction grating. When a heterogeneous beam is directed at the crystal, only the component with the wavelength corresponding to the angle of incidence is detected at the point of reception of the reflected ray. The registration of this reflected ray may be by means of an ionization chamber or a photographic film. Using photographic film, the regions of more intense radiation stand out as darker lines on the plate. Relative intensities throughout the film can be *measured* with a densitometer.[23] In short *density can be measured.*

Roentgen rays (and other sources of radiation), it is known, can produce numerous physical, chemical and biologic effects, many of which are of fundamental importance in roentgen diagnosis. In diagnostic roentgenology, the photographic and fluorescent phenomena caused by roentgen rays are converted to practical use. We also are aware that other important phenomena produced by these radiations are possible. Especially are we concerned with the chem-

ical and dehydrating effects of radiation which we have discussed and illustrated at length.

An example of the *chemical effect* has been reviewed and substantiated[20] by the discoloration of certain alkaline salts, a reaction which led Holzknecht in 1902 to methods of quantitative measurements of roentgen-ray intensities. Another example presented was the discoloration of barium platinocyanide used by Sabouraud and Noiré to measure roentgen rays as early as 1904. Many other chemical radiation effects have been observed since then.[8]

Finally, we have only to reapply the two premises above to the procedure of roentgen-ray diagnosis. This technical procedure permits the visualization of anatomic structures by roentgenographic means. A series of shadows outlines the various anatomic structures, and enables the visualization and study of their density, contour and size. Shadows are produced because more or less radiation is absorbed, depending on the density of the structure.

Our *first premise* offered proof that relative intensities throughout the film can be measured, *i.e.*, density can be measured.

The *second premise* supports the chemical effect of radiation in discoloration of chemicals in accordance with intensity of radiation, *i.e.*, chemical color change with irradiation.

Therefore, with the actual coloring of film possible as proven in the color prints we have made, color roentgenography remains only to be actuated.

EXPERIMENTAL CONSIDERATIONS

Many avenues of experimentation are open to investigation and to the final development of actual color in roentgenography. The first line of investigation which was thought most promising and practical concerned the fact that natural color photographs can be made on ordinary photographic plates or films designed for the production of negatives or positives in black and white. The colors are provided by finely divided silver or colloidal silver produced by development. The process involved is the result of the discovery that any black and white photographic image in gelatin can be converted by simple chemical procedures, including development, into a variety of colors of colloidal silver, depending upon the various densities present in the material treated.[5,23]

Seebeck discovered in 1810 that the color spectrum allowed to fall on a freshly prepared moist layer of silver chloride registered on the latter in colors closely corresponding to the colors of the spectrum itself. This was substantiated by Becquerel's observations in 1848. These observations alone pursued to fruition contain the promise of future direct color roentgenography.

It is of course common knowledge that any negative or positive can be transformed into a many-colored product simply by rehaliding, exposing to light and redeveloping. Similarly a roentgenogram can be transformed into a colored product with a variety of colors representing the various densities. However, this is not direct color roentgenography. In order to obtain direct color change the added chemical or dyes must be either present in the raw film or produced within the film in processing. With the first method the original emulsion contains the color-sensitive formers which may or may not be converted to the final dyes by developing and processing. Whereas, in the second method all the chemicals or dyes are produced or introduced in processing.[28] It is my goal and belief that the most satisfactory and direct method will be to have the color formers in the raw film which will be used to record the original image directly from the subject.

All of these chemicals and materials so far studied have shown a relative labile deterioration. In addition, complicating difficulties are found in the age of the film, temperature fluctuations, moisture conditions, sensitivity to light, and even to resultant chemical fumes.[28]

The contrast effects of color in roentgenography have been demonstrated in the color preparations previously made for

teaching and illustrated in the article "Simulated Color Roentgenography."[10] Resultant color changes in even the crudest of simulated roentgenograms permit easy detection and visualization of the major alterations from the normal. To the trained eye of the experienced radiologist this perhaps does not seem to be so outstanding. However, the actual significance of the incorporation and use of color becomes more profound as the recognition of structures delineated by color rather than by variable shades of black and gray becomes familiar. It is to be stressed and re-emphasized that the process does not "reflect" or "record" the color of the various organs of the body or organ systems. That is not the intention or the reason for color variation or incorporation. The color changes are intended to record in roentgen energy or "photons of energy" the differences in tissue density penetrated by the roentgen-ray beam and the resultant action upon the chemicals incorporated directly into the film emulsion. Visual acuity is thereby enhanced by the additive color. In no way do we wish to detract from the excellence of the usual black and white roentgenogram, but to use it merely as a goal to the accomplishment of comparative color roentgenograms in experimental results.

Much experimentation is still necessary —finding of the exact chemical or chemical combinations that will record sensitively the slightest variation in roentgen-ray penetration is the actual goal. The expense and difficulty of the process will be reduced with knowledge gained, experience and efficiency. Color blind individuals will not find themselves at a disadvantage because as preliminary tests indicate it is the *contrast* differentiation of color that is important with no significant loss of interpretation in the color preparations. An aid to visual acuity and some amplification for the restricted eye of the radiologist is the only solution to the visual limitations of the present black and white roentgenography. The eye is the restricting tool of the diagnostic roentgenologist today. Direct color roentgenography will undoubtedly be achieved as we now have color photography and color cinematography, and the more recent color television.

SUMMARY

The theory and facts of direct color roentgenography have been reviewed. A short historic survey of the literature has been made to substantiate the theoretic presentation of color effect of roentgen radiation on various chemicals and chemical substances. Experimental details are not presented, but merely indicated because of the nonstandardization of experimental procedures at this time. The importance of color and color contrast is again stressed as an aid and amplification of the visual acuity of the radiologist.

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TELEVISION TECHNIQUES FOR CONTRAST ENHANCEMENT AND COLOR TRANSLATION OF ROENTGENOGRAMS*

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INFORMATION on a roentgenographic film may be converted to television video signals which now can be processed to enhance the difference in contrast between areas otherwise hardly perceptible; the brightness level of dark areas in the scotopic range of vision can be increased to the level of photopic or cone vision and finally, various tones of gray can be translated into different saturated colors. A description of these diagnostic roentgenographic gains and the apparatus by which they are produced is the subject of this report.

APPARATUS

The conversion of the information on the roentgenographic film to a television video signal is accomplished by a flying spot scanner system. Flying spot scanning of the roentgenographic film is not unlike some elements of the scanning which occurs in a television picture tube. The heart of this system is a scanning device which is a 5 inch diameter cathode-ray tube employing magnetic deflection and focus and operating at an anode potential of 30 kv. d-c with a beam current of 250 μa. (Fig. 1). Scanning of the cathode-ray tube produces a rapidly moving spot of light having a diameter of about 5 mils and 525 lines interlaced two to one are laid down in a frame period of 1/30th of a second. A rectangle of light or raster having dimensions of 4×3 inches is thus formed on the face of the cathode-ray tube. To reduce flicker in the displayed picture and still maintain a minimal band width of the video channel, interlaced scanning is employed. In this method of scanning, 262½ lines are laid down in a period of 1/60th of a second which is called a television field. During the succeeding field, the 262½ lines are laid down between the previous lines scanned. With this method of scanning, the large area flicker-rate is 60 cycles a second, well above that employed in standard motion picture projection, *i.e.*, 48 frames per second. Pictures may thus be displayed with high light brightness exceeding 100 foot lamberts without flicker. By way of comparison, motion picture screens seldom exceed a high light brightness of 10 foot lamberts.

The light from the raster is focused on an 8×6 inch area of the roentgenographic film by means of a lens. Since the transmittance of light through the roentgenographic film will depend on the optical density of each minute elemental area, the large diameter photomultiplier tube which is mounted directly under the roentgenographic film will respond accordingly. The time varying light signals are thereby converted into a time varying electrical voltage which is commonly called a video signal. Active scanning time of a line is 53 microseconds and during the flyback which occurs in 10 microseconds the electron beam in the flying spot cathode-ray tube is turned off. Thus is established a definite black level in the video signal. By utilizing a short persistence phosphor in the flying spot scanner tube (the light decreases to 10 per cent of its initial intensity in 1.2 microseconds) a high definition picture is procured.

The photomultiplier tube is 16 inches in diameter and has a cathode luminous sensitivity of about 30 microamperes per lumen. By means of the multiplier section of the phototube, a current gain of approximately 500,000 times is realized. The video voltage

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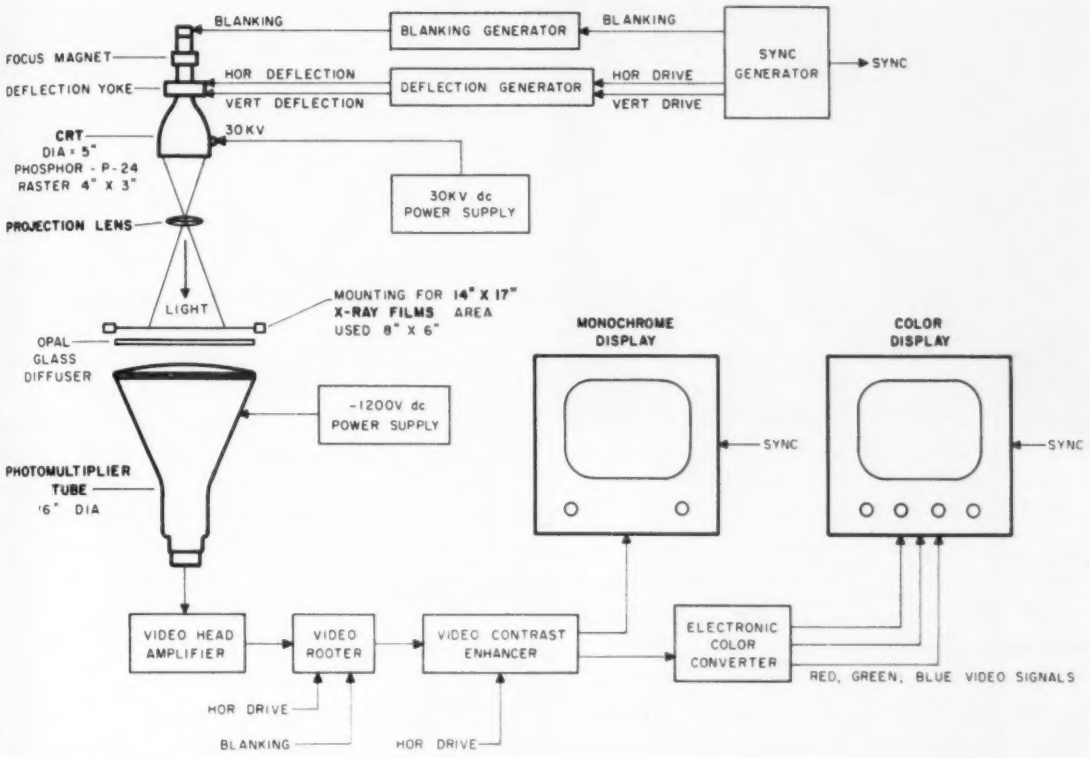

Fig. 1. Diagram of television circuits for contrast enhancement and color conversion of roentgenograms

delivered to the first stage of the video amplifier is approximately 0.1 volt peak to peak which is well above the noise level generated by this tube. Video amplification is employed to increase the voltage level to one volt peak to peak. This amplifier has a frequency response which is flat from 30 cycles per second to 8 million cycles per second and also includes circuits to compensate for the persistence of the phosphor in the cathode-ray tube. If this signal is fed to a black and white television monitor, it is necessary to gamma correct the video signal because of the nonlinear transfer characteristic of the television picture tube. The transfer characteristic of a television picture tube is such that the light output is approximately equal to the square of the input video voltage, producing compression of signals near black level and expansion of signals in the highlights. Since the photomultiplier tube is a linear transducer, a gamma corrector which takes the square root of the video signal is incorporated ahead of the monitor to produce an over-all linear transfer characteristic from the information on the film to the reproduced brightness. Rooting the video signal in this manner produces expansion of video signals near black level and compression of those in the highlights.

The principles of contrast enhancement can be best understood by considering a displayed picture on a television picture tube of a step wedge signal of 100 vertical strips, each differing from its neighbor by one foot lambert. Let us assume that the monitor is adjusted to display step one at a brightness of one foot lambert, step 50 at a brightness of 50 foot lamberts, and step 100 at a brightness of 100 foot lamberts. The difference in brightness between step 50 and step 49 is one foot lambert or 2 per cent which is barely discernible to the human eye. By electronic means, it is possible to clip all video voltage above and below

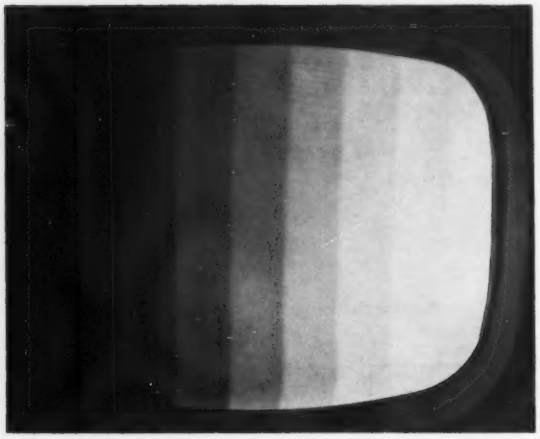

FIG. 2. Photograph of television monochrome monitor displaying a staircase of 10 tones of gray from black to white.

any given level and then restore the gain to its normal 100 per cent value. For purposes of illustration let us consider that all video voltages existing between black level and 45 per cent are clipped out so that step 45 becomes the new reference black level. In this case, step 50 has a new video level of 50-45 or 5 and step 49 has a new video level of 49-45 or 4. By electronic means, it is also possible to clip out any highlights not of interest. For purposes of illustration, assume that all video voltages above step 50 are clipped and limited to the 50 per cent level. Since in this illustrative case we have removed by clipping all video signals between black level and 45 per cent level and all video signals between 50 per cent and 100 per cent level, the video information of interest may be restored to the full dynamic range by increasing the gain by 20 times. The difference in brightness between steps 49 and 50, which could represent two adjacent areas of interest on a roentgenographic film, has therefore been increased from the former value of 49 and 50 foot lamberts respectively, *i.e.*, 2 per cent difference to $4 \times 20 = 80$ and $5 \times 20 = 100$ foot lamberts, respectively, *i.e.*, 20 per cent difference and now the contrast is readily perceptible.

The clipping and gain controls are arranged so that any selected portion of the full dynamic range may be displayed in contrast enhanced form for diagnostic purposes. To make this operation easy, an oscilloscope is incorporated in the equipment so that adjustment of the clippers and gain control settings can be quickly and accurately controlled.

It is true that a slight amount of contrast enhancement can be achieved by merely adjusting the brightness and contrast controls on a television picture monitor. The amount of contrast enhancement which can be obtained with our apparatus is *far greater*. Shown in Figure 2 is the picture displayed on the television monitor for a 10 step linear staircase signal. In Figure 3 improvement can be seen in the contrast between steps 4 and 5 when all video signals below step 4 and above step 6 have been clipped and the gain has been restored so as to use the full dynamic range of the monitor. This might correspond to changing the density contrasts in a roentgenogram from that between muscle and skin to that between muscle and bone.

COLOR TRANSLATION

In addition to the contrast enhanced monochrome display, it has been found advantageous in certain cases to display the various gray shades in different colors. The apparatus to make this color translation includes an electronic color converter and a color monitor, illustrated in Figure 1. The

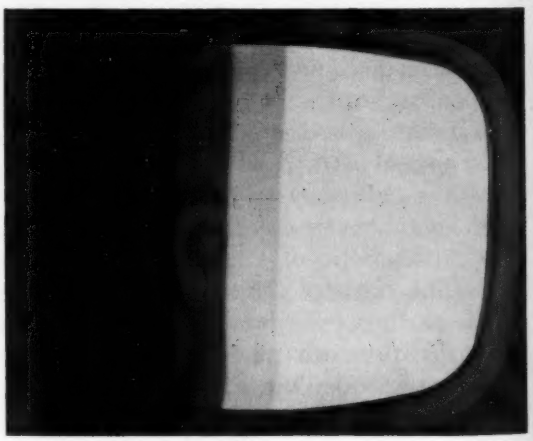

FIG. 3. Contrast enhancement of steps 4 and 5 in Figure 2 after clipping steps on either side and restoring contrast to the full dynamic range.

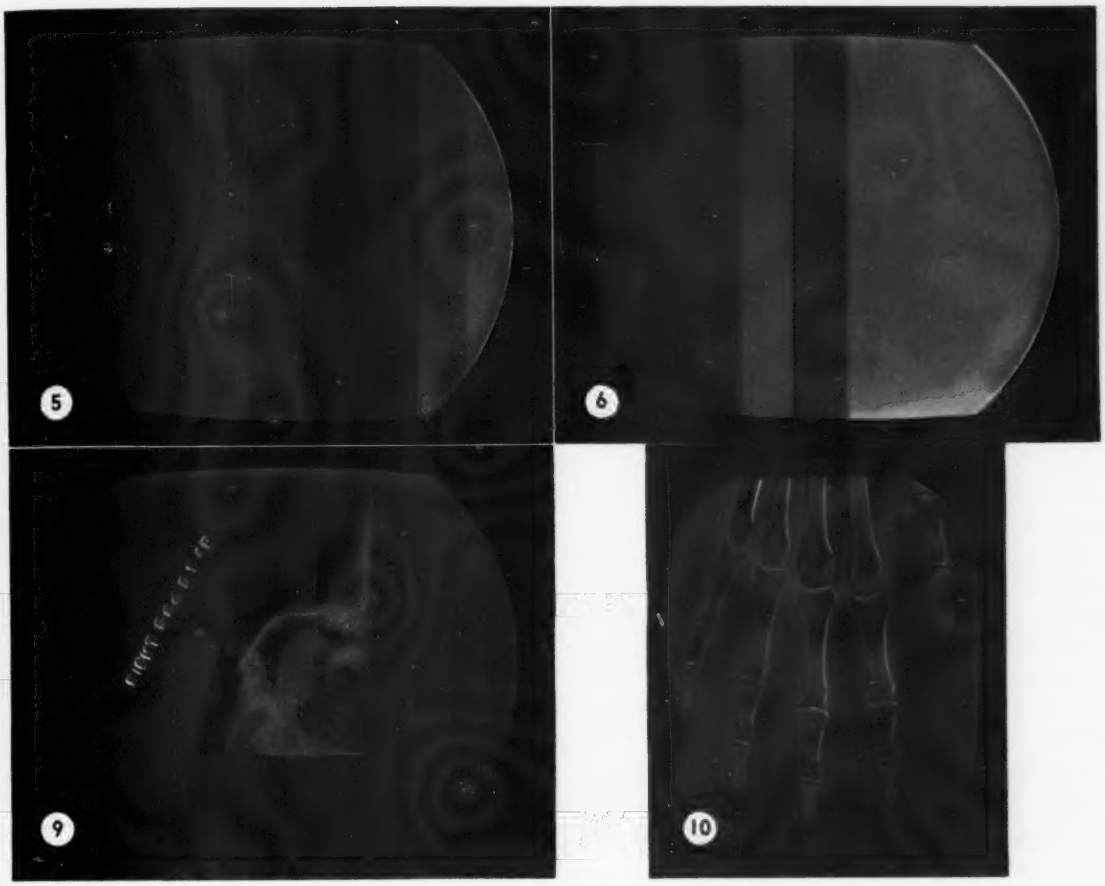

Fig. 5. Color translation of the 10 step staircase in Figure 2.
Fig. 6. Color translation of the enhanced contrast of steps 4 and 5 in Figure 3.
Fig. 9. Color translation of mammary carcinoma seen in Figure 8.
Fig. 10. Roentgenogram of a hand translating the various contrast densities into different colors.

color monitor is a 21 inch diameter cathode-ray tube employing separate electron guns for the red, green and blue signals. A contrast enhanced monochrome video signal is fed into the input of the color converter. By means of special video circuitry, the video voltages from black to white level are converted to saturated colors going through a color gamut of blue, cyan, green, yellow and red. One method of transformation which already has been found practical is to display video voltages near black level as blue, at 25 per cent level as cyan, at 50 per cent level as green, at 75 per cent level as yellow and at 100 per cent level as red. A diagram of this method of translation is given in Figure 4. Shown in Figure 5 is a photograph taken of the color monitor when the ten step linear staircase signal was applied to the input of the electronic color converter. Figure 6 illustrates the color contrast obtainable when video signals below step three and above step six are clipped and the gain is restored to normal. The authors are aware that the eye sees fine detail in an additive color picture in terms of luminance variations and also that the eye is not equally sensitive to color changes in various parts of the spectrum. Advances in the art may prove that different methods of color transformation to achieve greater color contrast and higher resolution may prove advantageous. However, the present method of translation

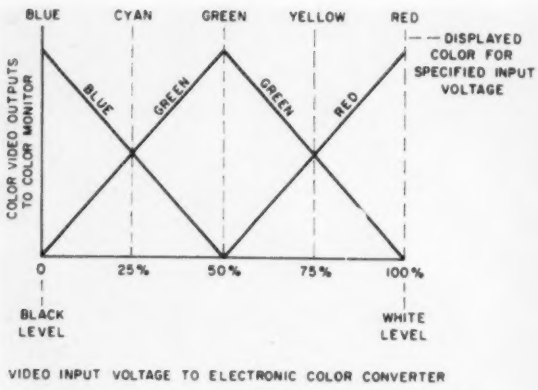

FIG. 4. Diagram relating video input voltage to electronic color converter.

helps greatly in identifying relatively small but separate areas of equal brightness because these are displayed in the same color on the color monitor. In many cases, it has been found desirable to utilize both the monochrome and color monitors to gain the fullest diagnostic information.

COMMENTS AND ILLUSTRATION

Since the eye perceives differences in brightness on a percentage basis, merely increasing the intensity of light behind a roentgenogram will not improve contrast. For instance, if the view box light intensity is doubled so that two adjacent areas which have a brightness of 49 and 50 foot lamberts are changed to a brightness of 98 and 100 foot lamberts, the percentage difference still remains 2 per cent. The visual contrast of the two adjacent areas remains unchanged. If brightness levels fall below 0.1 foot lambert, the human eye is further handicapped and fails to notice even 2 per cent differences because scotopic or rod vision takes over. Fine detail perception also becomes markedly decreased below this low level of brightness.

One of the drawbacks to be overcome in mammography is the enhancement of contrast between a neoplasm and the adjacent normal tissue. But with this system of contrast enhancement, an infiltrating neoplasm with its spiculated margins might be made to appear in greater contrast to the surrounding tissue as illustrated on the

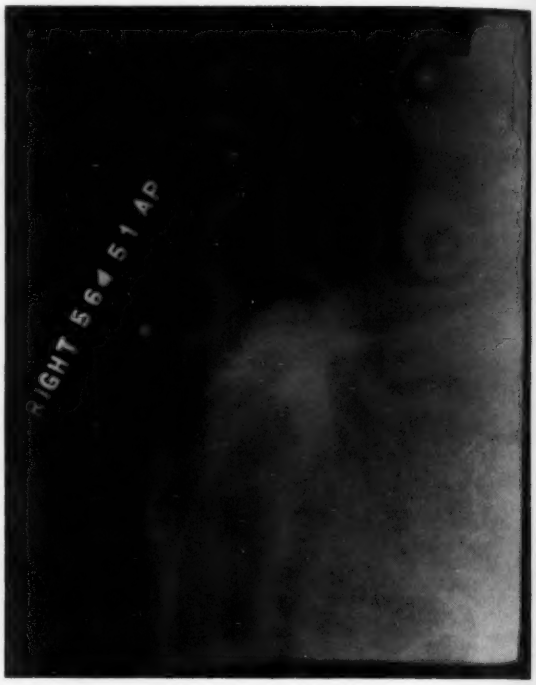

FIG. 7. Roentgenogram of a carcinoma of the breast, photographed from film on a view box.

television monitor in Figure 8. The same tumor as seen with transilluminance from any ordinary view box can be used for comparison (Fig. 7). Color translation of the neoplasm in Figure 9 further supplements the diagnostic information to be gained from the roentgenographic film. (As a simple illustration of color translation, a

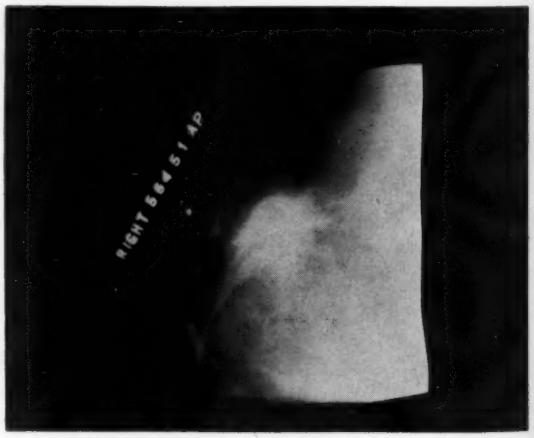

FIG. 8. Photograph of a televised display with contrast enhancement of mammary carcinoma in Figure 7.

hand in Figure 10 shows the full range of color translation of the various anatomic densities.)

A fascinating experience takes place during manipulation of the television controls during clipping and restoration of the dynamic range of contrast enhancement. As the various degrees of contrast enhancement are tried, an impression of anatomic dissection is gained. It is as if one were looking at a series of laminagrams in different densities. Many new densities come to light in kaleidoscopic succession not present in any one adjustment of the dials.

Contrast enhancement also is useful in high as well as in low brightness levels. In cardioangiograms, the blood columns in the high brightness levels can be shown in greater contrast to the opacified blood bolus. These increased contrasts, moreover, can be translated into different colors. The exact extent of the opacified blood column is easily identified. Abnormal shunts as well as other details become more readily discernible.

Only the beginning has been made with these new techniques. With further improvements, much additional aid should become available to the roentgenologist in coping with contrast difficulties of the roentgenogram.

SUMMARY

A new apparatus and television techniques are described for contrast enhancement and color translation of roentgenograms. The limitations of the human eye for contrast perception are reviewed and illustrations are given of the television techniques which partially overcome these ocular limitations. Improved contrasts on a television monochrome monitor supplemented by color translation on a color monitor results in a gain of diagnostic information from the ordinary roentgenogram which can be varied over a wide range. With this additional information, the limits of roentgenographic diagnosis are extended.

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Fortieth Annual Meeting: Hollywood Beach Hotel, Hollywood Beach, Florida, March 27–29, 1958.

EDITORIALS

PROGRESS TOWARD A COMPREHENSIVE PROGRAM IN RADIATION SAFETY

THERE is perhaps no radiologist who has not, at some time or another during the past year or so, first been angered and then embarrassed at the widespread publicity given to the dangers of excessive radiation exposure in the public press. The anger has arisen from the all-too-frequent flagrantly sensational manner in which radiation hazards have been reported; the embarrassment has occurred from the realization that clinical radiologists, faced for many decades with the dangers of radiation, often have been careless in the use of radiologic apparatus and, perhaps more important, have often been unable to give answers to many fundamental questions where the actions of radiation on biologic systems are involved.

As a result of public concern, a number of nationally sponsored committees have been vigorously at work studying various aspects of the radiation exposure problem. Among these may be included the Committee on Radiology of the National Research Council, the National Committee on Radiation Protection, and the Radiation Study Section of the National Institutes of Health. In addition, numerous other scientific and semi-scientific groups have had these matters under serious consideration. In each case, the objective of the Committee has been a review of the radiation problem as it pertains to the area of committee responsibility and the development of ways and means to correct such practices as are found from this review to be hazardous.

Although each of these committees has faced its task with great responsibility, it has become evident, as time has passed, that much of this committee work may not be as effective as desired. The reasons for this I believe are two-fold: (1) There is no one committee in this country with a continuing, comprehensive responsibility in the field of radiation control; and (2) There are few committees involved in radiation matters which have available to them mechanisms wherein their recommendations may be assuredly carried out.

To illustrate the need for comprehensive responsibility, let us consider the following matters. Those of us in clinical radiology are well aware of the hazards which pertain to our own specialty. However, the applications of radiation-producing machines and materials are not limited to the practice of medicine. They are found more and more often in industry, in agriculture, and in the food processing fields. Indeed, even a conservative look into the future indicates that the hazards of radiation exposure in industry alone, ten, fifteen, or twenty years hence, will potentially exceed those which exist today by many times. In addition, the activities of the military forces of the nation which, until a few years ago, have not been of great concern in the maintenance of the health of our people, now are creating a radiation problem of considerable magnitude.

During the past few years, it has seemed to many that if effective control of the radiation hazards which confront the people of the United States today and in the years to come is to be attained, the radiation problem must be faced on a comprehensive basis and within an operational framework such that those who apply their time and effort to radiation safety may be assured that their recommendations may be trans-

mitted into effective action. Furthermore, it has appeared to an increasing number of responsible physicians and scientists that the United States Public Health Service should take the lead in the development of just such a program. By law, the Service has primary responsibility for the maintenance of the health of the nation. Unlike other government agencies whose scope of interest in the radiation field is limited, the Public Health Service has the responsibility to our people to view the radiation problem from the broadest possible viewpoint. Finally, the Service, either by existing legislation or by possible legislation in the future, has the mechanisms whereby such control methods which, in the judgment of our best men in medicine and science, seem desirable, may be put into action.

Unfortunately, the Service in past years has developed no great competence in radiation affairs to support such responsibility. This has largely reflected a distressing lack of interest in these matters at high levels of authority and an assumption that radiation problems in public health could be effectively met by the Atomic Energy Commission, even though the latter agency's interest in radiation hazards is limited to its own circumscribed activities.

During the past summer, Secretary of Health, Education and Welfare Marion B. Folson and his newly-appointed Surgeon General, LeRoy E. Burney of the United States Public Health Service, recognized clearly the important role which the Service must play in developing a comprehensive radiation program in the health sciences. They also recognized that, to accomplish this objective, the Service will need the assistance and guidance of every individual, organization and society which has competence in those branches of the medical sciences where radiation is involved. For instance, the three national committees mentioned in an earlier paragraph, will be encouraged to play an even more vital role in the radiation programs they have pursued in the past.

To begin the work of the Service, the Surgeon General is currently forming a National Advisory Committee on Radiation which will be directly responsible to him. This committee will include men in a broad range of scientific and ancillary disciplines, including clinical radiology, radiobiology and radiation physics. It is anticipated that the Committee will be relatively small, since much work is required, and this can be most readily effected if the Committee is not excessively large. Its first job will be to evaluate the problems related to radiation and its hazards which affect the health of each one of us. Following this, it is anticipated that a comprehensive national program in radiation control will be developed. Finally, such legislation as may be necessary to place this program in operation will be sought.

One can only anticipate the areas of primary concern in the deliberations of the National Advisory Committee on Radiation. However, the history of the past few years makes it abundantly clear that great attention must be given to the development of fundamental and applied research programs whereby a better understanding of the effects of radiation on biologic systems may be gained, and whereby improved standards of safety may be developed.

In addition to problems in research, the needs of our scientific and medical schools in radiologic education will be studied with great care. At the present time, there is a great insufficiency of well-trained people in those fields of the medical sciences where radiation protection problems are important. As a result, considerable assistance must be given to our medical schools, schools of hygiene and schools of engineering by way of grants for building construction, faculty additions, and research fellowships, so that these schools may provide the climate wherein competent people in radiation affairs may be educated.

Ways and means of meeting *today's* problems, before the longer-range effects of future research and education come into play, must also constitute an area of serious deliberation. Furthermore, since the

hazards of radiation exposure constitute only one of a group of environmental health problems which exist in our country today, (for example, chemical toxins distributed in the air by industrial plants constitute an increasingly serious matter), it is important that this be recognized and that radiation control methods not be developed as an isolated program but in their proper relationship to environmental health problems as a whole.

In closing, there is one thing that might be well to point out, since it is of great importance if the freedom of the scientific and medical professions of our country is to be maintained. The Public Health Service historically in the conduct of its programs operates as an advisory agency rather than as a regulatory force. As far as regulatory matters are concerned, it has consistently left these to the regional, state and local community to conduct; one can anticipate that such will be the case in the future. Furthermore, in its great programs in support of medical research during the past few years, the Service has consistently followed a course wherein the individual investigator has retained the greatest possible freedom in the conduct of his work; again, the same practices may be anticipated in the field of radiation. This viewpoint, I believe, is important to remember because a sound radiation program can develop and flourish best within a framework of scientific freedom, with only such regulation as the public health demands.

With the foregoing developments, it is sincerely hoped that in the future, matters on radiation control may be more effectively met—supported by comprehensive research at both the fundamental and applied levels and by the development of well-trained people who are able to do the job which is required of them. Certainly, this is the objective of the program on which the United States Public Health Service has embarked. As I have indicated heretofore, it will utilize every possible resource to insure its being a program of which all of us can be proud.

Johns Hopkins University
and Hospital
Baltimore, Maryland

Russell H. Morgan, M.D.

SYDNEY JAMES HAWLEY
1899–1957

RADIOLOGISTS throughout the country were saddened to learn of the passing of another familiar figure from the national scene, when Sydney James Hawley died in Seattle on Monday, July 29, 1957. He had been quite ill during the past year and so the event was not entirely unexpected but still leaves a void in the hearts and minds of many of us in this field and the many other diverse areas in which he was interested.

Dr. Hawley was born in Seattle in 1899. He served in the United States Army Engineers during World War I. After the war, he completed his pre-medical work at the University of Washington and then ob-

tained his medical degree from the University of Pennsylvania Medical School in 1924. He interned at the George F. Geisinger Hospital in Danville in 1924 to 1925 and immediately developed an interest in radiology. His training was under Dr. Willis F. Manges in Philadelphia. He then returned to the Geisinger Hospital where he was associated with it in the Department of Radiology until 1946. During this period he was also consultant radiologist to the Danville Street Hospital.

In 1946, because of family ties, Dr. Hawley returned to Seattle and opened a private office. He was consultant also to the United States Marine Hospital in Seattle.

Dr. Hawley keenly felt his responsibilities to organized radiology. He was active not only in the American Roentgen Ray Society but served on the Board of Chancellors and was chairman of several important commissions in the American College of Radiology. His many activities in the Radiological Society of North America culminated in his being elevated to the position of president-elect in December, 1956. He was a founder and the first secretary of the Pacific Northwest Radiological Society and became its President in 1955.

His scientific writings show an insight into the relative values of some concepts long before they gained general acceptance. In articles published in 1939 and 1942, he pointed out the value of rotation therapy and also wrote in this period on the use of filters in diagnostic roentgenology. He held the appointment of Clinical Assistant, Professor of Radiology at the University of Washington School of Medicine.

One of Dr. Hawley's major interests, since returning to Seattle, was the Anti-Tuberculosis league to which he devoted much time and held many important positions. He was also interested in the Children's Orthopedic Hospital of Seattle.

Syd was truly a cultured and learned man in the broadest sense. He was a pianist of recognized ability. While in Pennsylvania, he was a member of a painting group and later maintained his interests in the Seattle Art Museum. He was also a member of the Seattle Historical Society. His interest in languages was manifested by his constant study of Spanish and French. When he was invited to appear on a program in Cuba several years ago, he presented his papers in Spanish and acquitted himself very creditably.

His many friends throughout the country join with his family and Seattle colleagues in mourning for the passing of a true gentleman and a scholar.

Thomas Carlile, M.D.

SOCIETY PROCEEDINGS AND NEWS ITEMS

AMERICAN CANCER SOCIETY OFFERS CLINICAL FELLOWSHIPS

The American Cancer Society has announced that Clinical Fellowships at the senior resident level for the academic year 1959–60 may be applied for by institutions accredited by the Council on Medical Education and Hospitals of the American Medical Association to give training in the following specialties and sub-specialties, with emphasis on the diagnosis and treatment of cancer: internal medicine, malignant diseases, neurological surgery, obstetrics-gynecology, orthopedic surgery, otolaryngology, pathology, public health, radiology, surgery, and urology.

Institutions will be notified of awards granted in June, 1958. Individual candidates should apply directly to an institution, or the American Cancer Society, for information concerning fellowships. The annual stipend, tax exempt, is $3,600.

Application forms are available from the Director of Professional Education, American Cancer Society, Inc., 521 West 57th Street, New York 19, New York.

February 15, 1958 is the deadline for institutions submitting applications for the 1959–60 clinical fellowships.

MEETING OF NEWLY INCORPORATED EASTERN RADIOLOGICAL SOCIETY

The first meeting of the newly incorporated Eastern Radiological Society will be held on May 5, 6, 7, and 8, 1958, at Mid-Pines Club, Southern Pines, North Carolina. Reservations should be made early with the hotel management. Further information and application forms for membership in the Society may be obtained from Dr. Barton R. Young, Germantown Hospital, Philadelphia 44, Pennsylvania, President; Dr. George R. Krause, 10900 Carnegie Avenue, Cleveland 6, Ohio, Vice-President; or Dr. John D. Osmond, Jr., Euclid-Glenville Hospital, Cleveland 19, Ohio, Secretary-Treasurer.

NINTH INTERNATIONAL RADIOLOGICAL CONGRESS ANNOUNCED

The Ninth International Radiological Congress will take place from July 23 to 30, 1959, in Munich, according to the President, Dr. B. Rajewsky. As at previous congresses, an extensive technical exhibition will be held in Munich to give industrial manufacturers an opportunity to display their products. Firms who would like to participate are requested to contact the managing chairman of the exhibition, Dr. H. Messinesis, Mönckebergstr. 7, Hamburg 1, Germany.

EASTERN CONFERENCE OF RADIOLOGISTS TO BE HELD IN PHILADELPHIA

The Eastern Conference of Radiologists will be held on March 6, 7 and 8 at the Bellevue-Stratford Hotel in Philadelphia, Pennsylvania. Registration will be on Thursday afternoon and evening, March 6. Communications regarding the conference should be addressed to Dr. Nathan P. Salner, Secretary, 6812 Castor Avenue, Philadelphia 49, Pennsylvania.

AMERICAN SOCIETY OF X-RAY TECHNICIANS TO MEET

The American Society of X-Ray Technicians will hold its Thirtieth Annual Convention from June 7 through 12, 1958, at the Adolphus Hotel, Dallas, Texas.

ORINS CONDUCTS COURSE IN VETERINARY RADIOLOGICAL HEALTH

The Oak Ridge Institute of Nuclear Studies has announced that a special two-week course in veterinary radiological health will be conducted at Oak Ridge, Tennessee, March 10–21. Conducted for the United States Atomic Energy Commission by the ORINS Special Training Division, the course will be presented with the cooperation of the University of Tennessee-AEC Agricultural Research Program and the U. S. Armed Forces Veterinary Corps.

Detailed information and application blanks may be obtained from the course director, Major Max Nold, U. S. Air Force Veterinary Corps, ORINS Special Training Division, P. O. Box 117, Oak Ridge, Tennessee, or from Dr. Ralph T. Overman, chairman of the division, at the same address.

INDUSTRIAL ISOTOPE RADIOGRAPHY COURSE OFFERED BY ORINS

Applications are now being accepted by the Oak Ridge Institute of Nuclear Studies for participation in a two-week course in industrial isotope radiography, to be held in Oak Ridge, Tennessee, May 5–16. Deadline for application for participation in the course is March 15, 1958. Brochures describing the course in detail and application blanks are available from Ralph T. Overman, chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

RETROPNEUMOPERITONEUM UND PNEUMOMEDIASTINUM. By Prof. Dr. U. Cocchi, Zürich. Cloth. Price, DM 67.50. Pp. 226, with 142 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1957.

This beautiful monograph on retropneumoperitoneum and pneumomediastinum fills a gap in the German language literature of roentgenology, and for that matter in the world literature. The material is based on a large personal experience and an admirable review of the literature of the whole subject. It sets forth clearly the field of application and leads to some reliable conclusions concerning the present value and possible further development of this subject. A commendable amount of conservatism is manifested in the statement of indications of pneumomediastinum. The procedures of retropneumoperitoneum based on the older technique of pneumoperitoneum and perirenal gas filling have been largely replaced by retropneumoperitoneum, which with proper indications may be recommended for use in the clinic. This monograph can be depended upon as an indispensable guide in air contrast studies in these retropneumoperitoneal and pneumomediastinal procedures. Use is made of the technique described by Ruiz Rivas and by Gennes and his collaborators. However, a large number of different techniques are presented with exact illustrative drawings and descriptions of procedures for accomplishing both retropneumoperitoneum and perirenal emphysema. The illustrations are superb and very complete.

The author gives thanks to a number of colleagues who have assisted him in accumulating the cases. A more or less summarized abstract of the book is included in the forthcoming publication of the English translation of the five year Supplement to the four volume textbook on Roentgen Diagnostics by Schinz and his colleagues, published several years ago by Grune & Stratton, the translation having been supplied by James T. Case, M.D. and colleagues. The possibilities of these new methods of air contrast roentgen examinations are inviting.

JAMES T. CASE, M.D.

TOPOGRAPHISCHE AUSDEUTUNG DER BRONCHIEN IM RÖNTGENBILD. By Priv.-Doz. Dr. C. Esser, Mainz. Second edition. Cloth. Price, DM 58.—. Pp. 210, with 89 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1957.

The first edition of this monograph on bronchial topography appeared in 1951, and was translated into Italian in 1953/4. The present, second edition has been considerably enlarged, and includes an almost encyclopedic survey of the bibliography. In this book, the segmental bronchi are identified in accordance with the international agreement, reached at the London conference in 1949, largely as a result of the efforts of the British Thoracic Society. For subsegmental bronchi, which cannot be understood adequately without reference to pulmonary vascularization, the author follows the nomenclature of Boyden (U.S.A.). In the text, after naming the various synonyms under which it can be found in the literature, every bronchus and bronchiolus are considered from eight viewpoints: origin, variations, course, constancy and other characteristics, adjacent vessels, roentgenologic appearance, ramifications, and territory of distribution. Particular emphasis is placed on tridimensional visualization, and it seems that at times the only way to achieve adequate mapping *in vivo* is by laminagraphy.

Some of the reproductions of fine bronchial ramifications have an almost artistic tint, in keeping with the excellent typographic presentation, which has become a trade-mark with the Thieme publishing house. Also otherwise, this monograph may be recommended as a desirable addition to any radiologic library. It will prove to be an invaluable reference manual for all those interested in pulmonary diseases.

E. R. N. GRIGG, M.D.

FUNDAMENTALS OF CLINICAL FLUOROSCOPY. By Charles B. Storch, M.D., Associate Attending Roentgenologist, Radiodiagnostic Department, Beth-El Hospital, Brooklyn, New York. Second revised edition. Cloth. Price, $8.75. Pp. 305, with 318 illustrations. Grune

& Stratton, Inc., 381 Fourth Avenue, New York 16, New York, 1957.

In this second edition, the author revised and expanded many portions of his book, including new sections on small bowel and intestinal obstruction, and congenital heart disease, and has succeeded in improving an already fine text. The basic objective is to orient the clinical fluoroscopist in the simplest, and yet most useful, adjunct to roentgenographic diagnosis. Fluoroscopy in trained hands affords a quick, convenient, and easy method of surveying the suspected area of pathology, of predetermining the most advantageous positions for roentgenographic exposure, and of spot-checking any questionable aspects of the roentgenogram. He points out, however, that fluoroscopic impressions are usually only tentative and must await finality based upon study and correlation with the more detailed roentgenographic findings.

This book is a well organized, easily understandable practical manual outlining the features and pitfalls of clinical fluoroscopy. An abundance of carefully chosen illustrations, provocative questions and their answers, and an up-to-date bibliography complement the author's graphic descriptions of the fundamental principles necessary to gain a fluoroscopic intuitiveness. The book is recommended to all radiologists, medical students, house staffs, and practicing physicians interested in acquiring insight into the field of the extensively used clinical fluoroscopy.

Donald M. Monson, M.D.

Radiological Diagnosis of Bronchiectasis. By Carl Benignus Arthur Julien Puijlaert. Paper. Pp. 46, with 44 illustrations. H. E. Stenfert Kroese N. V., 38 Pieterskerkhof, Leiden, Holland, 1957.

This is a monograph of 46 pages of text and an atlas of 12 illustrations. It is based on the records of 450 patients seen between 1950–1954 at the University Hospital at Leiden. Much of the data has been collected from chest conferences with the "Thorax Team" of the same hospital.

The monograph is divided as follows: (1) "The analysis of the radiological picture in straight radiography; (2) the diagnostic significance of planigraphy; (3) a directed method of bronchography; (4) clinical symptoms leading to the use of bronchography."

Perhaps the chief contribution of the author is the description of an ingenious tilting table which allows examination of the patient with a horizontal roentgen beam during bronchography. This aids in the performance of selective segmental bronchography which the author employs with meticulous detail. Antibiotics are administered routinely for several days before bronchography to reduce the amount of exudate in the bronchial tree. Amyl nitrite is often used during the procedure to reduce bronchial spasm, and to aid in more complete filling.

The author does not mention the important complementary role of bronchoscopy in the diagnosis of bronchiectasis and the preparation of the patient for bronchography. The diagnostic value of conventional roentgenography and laminagraphy may be somewhat overemphasized in the monograph. No mention is made of the importance of roentgenograms in full inspiration and expiration during bronchography, as a means of determining the amount of elasticity remaining in the diseased lung in order to estimate whether the bronchiectasis is reversible or not. This is of particular importance in young patients.

However, the monograph is a concise, well-written review of the problem of the diagnosis of bronchiectasis, and as such is of interest to all radiologists. The illustrations are of excellent quality and demonstrate well the points which the author wishes to make in the text.

Robert P. Barden, M.D.

Contribution à l'étude du syndrome endocrinien provoqué par l'irradiation totale de l'organisme. By E. H. Betz, Chef de Travaux à l'Université de Liège, Associé du Fonds National de la Recherche Scientifique. Paper. Price, 2,800 fr. Pp. 326, with 71 illustrations. Masson et C^{ie}, Éditeurs, 120 Boulevard Saint-Germain, Paris, 6^{e}, France, 1956.

This book is a contribution to the study of the endocrine syndrome induced by irradiation of the whole body.

There are 9 chapters dealing with the various phases of the influence of irradiation on the adrenal, thyroid and gonadal secretion and activity.

These chapters are followed by a résumé of the results and there is a bibliography of 21 pages.

The résumé presents the observations made on certain endocrine reactions following total

body irradiation of animals (rats and mice). The main interest was on the influence of the endocrine disturbances and the reaction of resistance of the animal as it affects the regeneration of hemopoietic tissues after roentgen irradiation. Previous researches showed that a parallelism exists between the resistance to irradiation and the power of regeneration.

The researches were limited to three glands, the secretory activity of which is subject to the control of the hypophysis, *i.e.*, the adrenal, the thyroid and the gonads. The endocrine activity of the gonads appeared to be little modified after one sublethal dose (500 r), whereas there was a moderate stimulation of the adrenal cortex and the thyroid. The stimulation of the mouse's adrenal cortex after irradiation accelerated the death of the treated animal by a lethal dose of roentgen rays. The results are comparable to those obtained by utilizing the many, diverse agents which are capable of stimulating the adrenal—roentgen rays, cold, sodium salicylate, and ACTH. Preliminary stimulation of the adrenal reduces considerably the reaction of the adrenal when irradiated at the same time. Any active stimulus to the adrenal after irradiation exerts a cumulative effect and accentuates the reaction of the adrenal. The injection of desoxycorticosterone acetate does not affect to any degree the resistance to irradiation whereas cortisone has an unfavorable effect on the irradiated mouse.

The various results are discussed and tend to prove that hyperactivity of the adrenal constitutes an unfavorable factor in an animal that has been irradiated. The activity of the thyroid did not influence to any extent the resistance to irradiation, nor did thyroidectomy or injection of moderate doses of thyroxin modify the survival of irradiated mice.

The researches on the protection conveyed by thiouracil showed that the mechanism of action of this substance is different according to the mode of administration. When thiouracil is given many days before irradiation, it modifies the resistance by way of the endocrine mechanism but it does not produce the protection conveyed by hypothyroidism. The change in resistance by the animal treated with thiouracil is more severe than that induced by lessening of adrenal activity. The prolonged administration of oral thiouracil diminishes considerably the reaction of the hypophysial-adrenal axis induced by the stress of irradiation. Previous castration, followed by a large dose of testosterone proprionate or estradiol benzoate for many days before irradiation decreases the resistance. The mechanism of this action is not completely clear.

Castration probably augments the decreased activity of the pituitary-adrenal glands.

The study of hemopoietic regeneration after irradiation shows that a sublethal dose of radium—(500 r) is rapidly followed by considerable regeneration of hemopoiesis; after a lethal dose there is practically no repair of hemopoietic tissue. The injection of large doses of cortisone is capable of inhibiting regeneration of hemopoiesis in the rat receiving sublethal irradiation dosage. The injection of substances which increase protein anabolism, (somatotropic, testosterone proprionate, vitamin B_{12}) has a favorable effect on the hemopoiesis of the rat irradiated with a lethal dose. These researches confirm the inhibiting effect of the adrenal on hemopoiesis since there is an antagonism between the adrenal cortex and the substance capable of stimulating repair of the hemopoietic apparatus of the irradiated rat. Thyroxin does not influence the regeneration of myeloid tissue of the irradiated rat but stimulates the regeneration of lymphoid tissue.

The author discusses the antagonistic effect between the adrenal cortex which inhibits lymphopoiesis and thyroxin which stimulates it.

This book is particularly interesting for radiologists and endocrinologists. The printing is large, and therefore easily read. The bibliography of 21 pages attests to the immense amount of research which went into the work.

Robert C. Moehlig, M.D.

ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. LEUCUTIA, M.D., Harper Hospital, Detroit 1, Michigan

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ROENTGEN DIAGNOSIS

Head

Rimpau, A., and Seils, H. Pathologisch-anatomische Befunde an der Punktionsstelle bei der Hirnarteriographie und Betrachtungen zur Punktionstechnik. (Pathologic-anatomic findings at the puncture site in cerebral arteriography and discussion of the puncture technique.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, August, 1957, *87*, 191–199. (Address: H. Seils, Chefarzt der Röntgen-Abt. des Allgemeinen Krankenhauses, Hamburg-Rissen, Germany.)

This article is based on nearly 200 cases of percutaneous carotid arteriography. The pathologic and clinical aspects are discussed at length.

Minimal hemorrhage into the vessel sheath and surrounding musculature can be observed in almost all recent puncture cases. When a larger hematoma (8 per cent) develops, puncture of the adjacent jugular vein is usually the cause of the bleeding. In practically all cases the needle tip left a mark opposite the site of the puncture. Intramural injection also occurred followed by dissecting aneurysm. Most complications were noted when the internal rather than the common carotid artery was injected.

Clinically, complications due to percutaneous injection are rare. When delayed neurologic findings, however, become manifest, the possibility of carotid puncture damage with impaired blood flow has to be considered. Therefore, a meticulous technique is imperative for the prevention of complications.

The needle must have the proper diameter and a sharp, but short point. After piercing of the skin the needle should be brought to the point of maximal pulsation. The artery can then be pierced either with a short, jerk-like, maneuver or, instead, one increases the pressure of the needle gradually until blood flows into the attached syringe. Although the needle seems to be within the lumen of the artery, its tip may have already progressed to the opposite side of the arterial wall. In such instance, part of the contrast material will be injected into the vessel wall, thereby causing dissecting aneurysm and extraluminal location of the needle point. Therefore, a saline solution should be injected first for testing purposes. When blood returns freely after this injection, proper intraluminal location of the needle is assured.

Many further details are discussed and illustrated in the article. These should be of special interest to surgeons specializing in percutaneous angiography.—*Ernest Kraft, M.D.*

Neck and Chest

Gros, C. M., Sigrist, R., and Burg, S. La pneumomastographie. (Technique du radiodiagnostic des kystes du sein.) (Pneumomastography [roentgen diagnostic technique for breast cysts].) *J. de radiol., d'électrol. et de méd. nucléaire*, May–June, 1957, *38*, 389–392. (From: Centre anticancéreux, Strasbourg, France.)

Breast cysts are tapped with a needle as used for intramuscular injection. The intracystic fluid is aspirated and kept for cytologic examination. Then a volume of air (slightly less than the aspirated fluid) is injected into the cyst and roentgenograms are taken in the longitudinal (craniocaudal) and, if necessary, oblique or other views of the mammary gland.

The authors present 3 cases with 6 pneumomastograms and discuss the clinical, cytologic, conventional roentgenographic and pneumomastographic findings. The first case was that of benign cystic diffuse fibroglandular hyperplasia. The second was that of sclerotic chronic mastitis. The third case showed clinically and roentgenologically evident scirrhus epithelioma of the left breast, whereas on the right, two foci of epithelioma were convincingly demonstrated by pneumomastography (a deep retromammary cystic epithelioma and another smaller stellate of the inferomedial part of the breast). This pneumomastography can differentiate between a simple, a hemorrhagic and a neoplastic cyst of the breast in addition to providing fluid for cytologic examination.—*Jirair N. Sarian, M.D.*

Abdomen

Benson, Clifford D., and Warden, M. James. Seven hundred and seven cases of congenital hypertrophic pyloric stenosis. *Surg., Gynec. & Obst.*, Sept., 1957, *105*, 348–354. (From: The Surgical Service, Children's Hospital of Michigan, Harper Hospital and Wayne State University Medical School, Detroit, Mich.)

The authors present a very comprehensive analysis of 707 consecutive cases of pyloric stenosis seen over the last sixteen years. Although the exact etiology of congenital pyloric stenosis is unknown, it is undoubtedly related to secondary changes in the imbalance of the neuromuscular mechanism resulting in hypertrophy affecting the circular muscle of the pylorus. In this series the ratio of males to females was approximately 4 to 1. The average onset of symptoms was 21.1 days. Vomiting was present in all cases, but not in one did bile appear in the vomitus. Projectile vomiting was an irregular finding primarily depending on the degree of obstruction. The finding of a mass in the right upper quadrant was confirmatory of the diagnosis, and a pyloric tumor was palpated in 68 per cent of the cases preoperatively. Of this series 25 per cent had roentgenologic studies.

The authors feel that preoperative preparation

has been very important in reducing the average hospitalization, which has decreased progressively during this period to an average of 5.4 days. The operative technique in all of these cases was essentially the same, using an incision extending the full length of the tumor and spreading the muscle widely with a Benson pyloric spreader. Perforation of the duodenal mucosa occurred only in 3 cases. In this series using the Fredet-Ramstedt procedure there were 4 operative deaths for a very low mortality rate of 0.6 per cent.—*Thomas D. Allison, M.D.*

Shoemaker, William C., and Wase, Arthur W. Absorption patterns of isotope labelled dietary constituents in postgastrectomy patients. *Surg., Gynec. & Obst.*, August, 1957, *105*, 153–158. (From: The Divisions of Surgery and Biological Chemistry, Hahnemann Medical College and Hospital of Philadelphia, Philadelphia, Pa.)

The authors describe a simplified method of measuring the assimilation of orally administered protein and fat in normal and postgastrectomy patients with Billroth I and Billroth II operations.

Human serum albumin labelled with I^{131} was given to 11 healthy controls and 7 patients prior to gastrectomy. Samples drawn from the peripheral blood at intervals up to six hours showed an early rise of radioactivity in the first half hour, reaching a maximum in about one hour. Six patients with Billroth I gastrectomies and 9 with Billroth II procedures were similarly tested. The Billroth I group showed a curve similar to the controls, although the initial portion of the curve was not quite as high. Billroth II gastrectomy patients showed a more rapid rise than the normals and Billroth I patients reached the maximum in thirty minutes. The decline in the peripheral radioactivity was slightly more rapid in the Billroth II group.

Corn oil, labelled by a method described by the authors, was also tested. Small amounts (3 ml.) of I^{131} labelled fat were given to 10 healthy persons and compared with absorption of larger amounts (63 ml.) in 13 persons. The small dose resulted in a maximum concentration in the peripheral blood in four hours. The larger dose required eight hours to reach maximum. Fifteen patients with Billroth I gastrectomies were tested; the 3 ml. test dose was used in 7 and the 63 ml. dose was used in 8. A total of 9 Billroth II patients were also tested with small and large amounts. A comparison of the controls with the gastrectomized patients who had been given the 3 ml. dose showed a more rapid initial rise in the peripheral blood in the latter group. When 63 ml. were given, the rapid initial absorption was more pronounced in the gastrectomy patients with consistently slightly higher levels in the Billroth I group.

The findings with labelled protein show that the alterations in the Billroth II as compared to the Billroth I group permit a more rapid emptying of the stomach with slightly less total absorption. With labelled fat, the absorption was shown to occur earlier and reached a maximum sooner in the gastrectomized patients. The absorption was appreciably lower in the Billroth II group due to bypassing the duodenum.—*William C. MacCarty, Jr., M.D.*

Arvay, N., Picard, J. D., and Bodiguel, A. L'examen radiologique d'urgence au cours des hémorragies digestives graves. (Emergency roentgenologic examination of patients with severe bleeding from the digestive system.) *J. de radiol., d'électrol. et de méd. nucléaire*, May–June, 1957, *38*, 393–397. (From: Clinique chirurgicale and Service de Radiologie, Hôpital de la Salpêtrière, Paris, France.)

In sketching the history of emergency roentgenologic examination of the gastrointestinal tract, the authors give credit to Hampton as being the first to practice it and the first to publish his conclusions, pointing out the quasi-innocuity of such a diagnostic procedure. Thirty-five patients with severe bleeding from the digestive tract (one had only 1,300,000 red blood cell count) were examined by the authors with no untoward effects. Only in one case had the roentgen examination to be interrupted and completed the next day.

The patients are submitted to the roentgen examination within one or two hours of admission to the hospital, often before transfusion. Of course, those in shock are first brought out of shock. Patients are transported and laid on the roentgen table, dispensing with fluoroscopic examination; roentgenograms in various views of the stomach and duodenum are taken after ingestion of barium, mostly in ventral decubitus position. Often a roentgenogram in the dorsal decubitus is taken first to rule out a gastric ulcer of the posterior wall. When esophageal varices are suspected, thicker barium is used.

Of the 35 patients, 15 had some type of ulcer (8 of the duodenal bulb, 5 gastric and 1 pyloric); 4 had cancer (3 of the prepyloric antrum and 1 of the fundus); 4 had esophageal hemorrhage (3 cases of varicosity and 1 of cancer); 6 cases most probably had bleeding ulcer of the duodenal bulb which could not be verified as no surgery was performed; 2 cases had gastritis (1 hypertrophic and 1 atrophic); 1 case had ulcer of posterior wall of stomach which was missed on the roentgen examination and 3 other cases had bleeding of the gastrointestinal tract which could not be detected or diagnosed by roentgenography.

The article points out the diagnostic importance of such examination and its innocuity.—*Jirair N. Sarian, M.D.*

Curry, Robert W. (Orlando, Fla.) Value of

the left lateral decubitus position in the roentgenologic diagnosis of acute abdominal disease. *Surg., Gynec. & Obst.*, May, 1957, *104*, 627–632.

The author emphasizes the usefulness of the left lateral decubitus position in the roentgen examination of the acute abdomen. He feels that, in general, radiologists and surgeons fail to recognize the diagnostic significance and interpretability of this position.

First of all, the positioning is important. The roentgenogram must include the abdomen from the right diaphragm to the iliac crest. The true lateral position is preferable, although the examination is still accurate even if the patient fails to maintain a true lateral position. Free air within the peritoneal cavity is well demonstrated in this manner, accumulating in small amounts between the lateral border of the liver and the adjacent wall of the abdominal cavity. In larger amounts, the air runs along the lateral wall of the abdominal cavity and outlines loops of small intestine and colon which lie adjacent to the lateral abdominal wall. Hodges and Miller state that as little as 1 cc. of free air can be detected in the lateral decubitus position, if the patient is positioned for thirty minutes prior to the roentgen examination. If as much as 3 cc. is present, then the prolonged period of positioning is not necessary.

Differentiation of the small and large intestine is usually not difficult and in most cases, the stomach is demonstrated. Usually air in the colon gravitates to the ascending colon, but in some cases the air may remain in the transverse or descending colon. In the stomach air gravitates to the distal end but some times some air may be also trapped in the fundus.

To prove the diagnostic accuracy of the left lateral decubitus position, the author used this position in a series of 119 consecutive cases of suspected perforation or intestinal obstruction in which upright position had also been employed. A detailed discussion and comparison is presented by the author of two views in respect to: (1) the detection of the presence of free air in the peritoneal cavity; (2) the detection of the presence of air and fluid level in the stomach, small intestine, colon and peritoneal cavity; and (3) the identification of the stomach, small intestine and colon.

The author concludes that the left lateral decubitus position of the abdomen can be used to replace the vertical position and is of comparable accuracy in demonstrating free air in the peritoneal cavity and air and fluid levels in the small bowel and colon. In a few cases, both the vertical and left lateral decubitus views will be required to demonstrate free air in the peritoneal cavity or to demonstrate intestinal obstruction. However, the author feels that in every case in which roentgenograms are taken to diagnose acute abdominal disease, both a vertical and a left lateral decubitus view of the abdomen, in addition to the supine view, should be utilized with the knowledge that the left lateral decubitus may be substituted for the vertical position if the patient's condition so necessitates.—*William C. MacCarty, Jr., M.D.*

McGARITY, WILLIAM C. Regional enteritis of the duodenum. *Surg., Gynec. & Obst.*, August, 1957, *105*, 203–209. (From: The Whitehead Department of Surgery, Emory University School of Medicine, Emory University, Ga.)

Regional enteritis may occur in the stomach, duodenum, jejunum, ileum or colon. It may be localized in a single region, it may occur in scattered areas, or it may manifest itself as a generalized process of the entire gastrointestinal tract.

A search of the literature reveals reports of only 25 cases in which the duodenum was involved. The surgical descriptions of the pathology appear to conform to nonspecific, granulomatous, cicatrizing inflammation of the duodenum.

The etiology of regional enteritis of the duodenum as well as that involving the remaining small bowel, stomach and colon remains obscure.

Four outstanding clinical features are: (1) Continuous or unlimited upper abdominal distress intensified by taking food and characterized by weight loss, weakness, nausea, and vomiting; (2) episodic and steatorrheal diarrhea; (3) gastric retention; and (4) signs and evidence of decreased absorption characterized by macrocytic anemia, lower concentration of serum protein and of serum calcium, and a flat glucose tolerance curve.

The average duration of upper gastrointestinal symptoms in reported cases was one year. In only two instances was the disease process limited to the duodenum. In all other patients, the associated lesions occurred prior to the duodenal involvement, concurrently with it or developed later.

During the early stages of the disease, roentgenograms may show only disturbed motility in the duodenum. Later various deformities of the duodenum become evident, followed by constriction which may progress to complete obstruction. As the process advances, peristalsis becomes diminished or absent. Irregularities in the mucosal pattern or even its complete loss occur to a varying degree. In most of the cases, the proximal duodenum and stomach were markedly dilated. Internal fistulas may develop. Repeated roentgen-ray studies are sometimes necessary before the diagnosis can be established in the early stages.

Regional enteritis of the duodenum has been treated in several ways, including deep roentgen therapy, duodenojejunostomy with or without vagotomy. The surgical treatment of choice in a patient with advanced regional enteritis of the duodenum, if the stomach and major portion of the

jejunum are not involved, appears to be a posterior gastrojejunostomy plus vagotomy.

The author reports on a new case in a forty-six year old woman.—*William C. MacCarty, Jr., M.D.*

Poppel, M. H., and Beranbaum, S. L. The indenture sign in acute exudative colitis. *Am. J. Digest. Dis.*, July, 1957, n.s. 2, 382–386. (From: The Department of Radiology, New York University-Bellevue Hospital, New York, N. Y.)

The indenture sign is the earliest roentgen finding of the acute exudative phase of colonic infection. It is a sign specific for an acute exudative inflammation of any etiology.

The indenture pattern is characterized by numerous indentations caused by swollen mucosal folds extending into the lumen and reducing its size. The area of involvement has no sharp demarcation, gradually merging with the normal portions. The peaks or serrations are usually of equal size and change simultaneously in size and shape, depending upon the size of the mucosal folds. They are not ulcerations, but represent barium extending in between the rather uniform swollen mucosal folds characteristic of acute exudative inflammation. The postevacuation study is especially important and thorough cleansing of the bowel prior to the examination is an important prerequisite. Irritability of the colon is rather pronounced and there may be tenderness on palpation. An air contrast study affords no additional diagnostic criteria and, in fact, is contraindicated in the highly inflamed bowel.—*J. F. Weigen, M.D.*

Wheeler, H. Brownell, and Warren, Richard. Duodenal varices due to portal hypertension from arteriovenous aneurysm; report of a case. *Am. Surg.*, August, 1957, *146*, 229–238. (From: Veterans Administration Hospital, West Roxbury, Mass.)

The authors present a very interesting and unusual case of aneurysm of the hepatic artery which developed a fistula to the portal vein. They believe that this is the first case reported which was diagnosed and treated during life.

During the multiple admissions to the hospital, a splenic phlebogram revealed the remarkably dilated duodenal veins and the obstruction of the portal vein at the gastrohepatic ligament.

The preoperative lumbar aortogram and the subsequent operation clearly delineated the large arterial aneurysm at the level of the hepatic artery. Because of the location of the aneurysm and the surrounding dense fibrotic tissue, modified aneurysmorrhaphy and wiring were required rather than resection and reconstruction of the artery.

The authors report that the result has been clinically satisfactory.—*Thomas D. Allison, M.D.*

Whelan, Thomas J., Jr., and Hamilton, George B. Annular pancreas. *Ann. Surg.*, August, 1957, *146*, 252–262. (From: Department of Surgery, and Department of Medicine, Valley Forge Army Hospital, Phoenixville, Pa.)

The authors present 3 personal cases and a review of 90 operative cases from the literature with an analysis of the incidence of other anomalies, such as associated peptic ulcer and pancreatitis, and the results of various methods of treatment. In these cases there was 43 per cent associated duodenal stenosis and atresia in children and 12 to 19 per cent in adults.

The 4 major complications of annular pancreas are: (1) Duodenal obstruction which may be acute or chronic; (2) peptic ulceration of the duodenum or stomach which occurred in 32 per cent of this series; (3) development of pancreatitis in the annulus; and (4) secondary involvement of the biliary tract with obstruction and jaundice.

The authors note that the diagnosis of the adult form of the disease is dependent exclusively upon the gastrointestinal roentgen studies. Here the dilated part of the first portion of the duodenum with the narrowed second portion are commonly found and the "double bubble sign" may be helpful. The differential diagnosis includes congenital bands; malrotation of the intestine; neoplasms of the duodenum; secondary tumors of the pancreas, kidneys, or retroperitoneal tissues; and cicatrizing duodenum following bulbar ulceration or adhesions after biliary tract surgery.

The authors feel that in an attempt to standardize the surgical therapy of this condition duodenojejunostomy is advisable as the treatment of choice when duodenal obstruction is present. Gastrectomy without division of the annulus is recommended in those cases associated with peptic ulcers. Only in those instances in which the annulus is the isolated site of pancreatitis, is resection of the ring suggested. Chronic pancreatitis and biliary tract problems require individualization of the surgical therapy.—*Thomas D. Allison, M.D.*

Boothroyd, Lawrence S. A. Annular pancreas. *Ann. Surg.*, July, 1957, *146*, 139–144. (From: The Department of Surgery, Royal Devon and Exeter Hospital, Exeter, England.)

The term "annular pancreas" describes a ring of anomalous pancreatic tissue around the second part of the duodenum. Approximately 100 cases have been reported in the literature, falling into 2 age groups: Infantile (from birth to four years), and adult (from seventeen years onward). No case has been reported between the ages of four and seventeen. The annulus is usually normal pancreatic tissue, often containing a central duct opening into

the main pancreatic duct. Distention and hypertrophy of the duodenal wall proximal to the obstruction is often remarkable. This seldom diminishes to any appreciable degree even after successful surgical intervention.

The clinical history strongly suggests peptic ulceration with pyloric stenosis and the differentiation from the history alone is usually impossible. Roentgenologic examination with the barium meal is the best diagnostic procedure, usually demonstrating some obstruction in the second part of the duodenum with proximal dilatation. In infants the classic sign is the "double bubble" of gas in the first part of the duodenum and in the stomach, like a transparent hourglass.

In adults the operation of choice is anastomosis of the proximal duodenum with the distal duodenum, or a conveniently placed proximal loop of jejunum. Direct interference with the annulus is to be avoided because of the danger of pancreatic fistula, and because division of the ring alone has often failed to relieve obstruction. In infants the principles are the same, but the size may make duodenal anastomosis impossible, and good results have followed gastroenterostomy.

Two cases are added to the literature on annular pancreas. In one case pancreatic ducts passed directly into the underlying intestine, hitherto unreported.—*J. F. Weigen, M.D.*

ESGUERRA-GÓMEZ, GONZALO. Excretion cholecystocholangiography; a study based on 1,400 cases examined with telepaque and/or cholografin. *Radiology*, July, 1957, *69*, 94–100. (Address: Clinica de Marly, Bogotá, Colombia.)

The author reports on the results of a study based on 1,400 cases examined with telepaque and/or cholografin. This study was undertaken in order to determine the normal appearance of the biliary tract; to learn to recognize the shadows which in certain cases of congenital anomalies serve the surgeon as a guide to successful operative intervention; and to discuss the value of the normal roentgenologic examination of the biliary passages from the clinical point of view.

Patients are given telepaque the afternoon before roentgenograms are obtained. If this oral medium fails to produce a gallbladder shadow, cholografin is immediately used. This technique is employed even in cholecystectomized patients, although the oral study may be dispensed with in some instances.

Among the numerous congenital anomalies found, the one of most importance is the presence of the outlet of the cystic duct on the left border of the hepatic duct after bordering the posterior aspect of the latter. Recognition of this anomaly will alert the surgeon and prevent his leaving a long fragment of cystic duct which may give rise to the reconstruction of a rudimentary gallbladder. This anomaly was found in 19 patients.

In conclusion the author stresses the value of demonstrating a normal gallbladder and normal extrahepatic biliary passages in the clinical evaluation of the patient. It is exceptional that a pathologic state exists in these structures when they have been visualized as normal.—*Donald N. Dysart, M.D.*

GYNECOLOGY AND OBSTETRICS

JULIANI, GIOVANNI, and SANNAZZARI, GIAN LUCA. Sulla comparsa di gas nella simfisi pubica al termine di gravidanza. (The presence of gas in the symphysis pubis at the end of pregnancy.) *Ann. radiol. diag.*, 1957, *30*, No. 3, 173–186. (From: Istituto di Radiologia dell'Università, Torino, Italy.)

A group of 50 women were examined during labor to determine what changes occurred in the symphysis pubis during this period. In 30 per cent of the cases presence of gas within the symphysis pubis could be seen. This was found with equal frequency in primipara and multipara patients.

The patients were examined in various positions, supine, upright—with legs in abduction and in adduction and it was found that this did not influence the findings in the symphysis pubis. A translucent vertical strip or strips were noted between the adjoining surfaces of the pubic bones. Sometime this gas was seen in women who had undergone labor many years before.

The authors believe that the explanation advanced by Bellucci for this phenomenon is the most plausible. A negative pressure within the joint capsule permits evaporation of the synovial fluid with release of gas from this fluid. This gas may collect in the interpubic space or under the interpublic ligaments so that its distribution as seen on roentgenograms may be variable.

The authors also mention the presence of air in the shoulder and knee joints, especially when these joints have been under prolonged traction.—*Peter E. Russo, M.D.*

GENITOURINARY SYSTEM

GRAAS, G., and MILLER H. Eine neue Methode zur Darstellung der Blase und ihrer pathologischen Inhalte. (A new method for demonstration of the bladder and its pathologic contents.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, August, 1957, *87*, 218–221. (Address: G. Graas, Christophstrasse 1, Göttingen, Germany.)

In spite of great technical progress in recent years, roentgenography of the bladder has remained unsatisfactory, especially for showing mucosal relief. Marked improvement, however, has recently been

achieved with a new contrast material "endografin Fl" which is a 50 per cent aqueous solution of 3-amino, 2,4,6-triiodine-benzoic acid methylglucamine salt.

The following technique is described: The bladder is catheterized and fully emptied with the aid of manual pressure from the outside. This is followed by instillation of 10 cc. of endografin Fl and 2 cc. of air through the catheter. Gentle massage is now applied for an even distribution of the contrast material. After this, most of the endografin is drained, which is followed by injection of ample amounts of air.

The method provides a satisfactory double contrast cystogram with good mucosal relief so that calculi, foreign bodies, also benign and malignant neoplasms can be recognized. For demonstration of diverticula, which in most instances are located posteriorly or posterolaterally, a prone position is preferable so that air can be forced into the sacs. The following advantages of the method are cited: (1) Cleanliness; (2) small quantity of iodine solution; (3) harmlessness; (4) tridimensional appearance; (5) low viscosity in spite of good adherence to the mucosa and foreign bodies; (6) mildness; and (7) a sterile procedure.

Several roentgenograms illustrate calculi, cystitis, prostatic adenoma, papilloma and a diverticulum containing a stone.—*Ernest Kraft, M.D.*

Cave, Paul, Rankin, J. A., and Mabbs, D. V. Experiences with I^{131}-labelled sodium acetrizoate in excretion urography. *J. Fac. Radiologists*, April, 1957, *8*, 250–257. (From: Radiodiagnostic Department and the Physics Laboratory, Royal Berkshire Hospital, Reading, England.)

In an attempt to learn how injected contrast material is distributed as to specific organs and concentration therein, and also to learn how the rate of excretion is affected by dehydration and by giving water before the examination and the variation in rate of excretion in different age groups, sodium acetrizoate tagged with I^{131} was employed as a contrast medium. Twenty-seven consecutive cases were examined. Trial and error showed that the readings were taken more satisfactorily with the patient supine.

Films of kidneys and bladder were exposed at five, ten, fifteen, twenty-five and thirty minutes after injection, and Geiger counter readings were noted on a previously prepared chart over the areas of the liver, spleen, both kidneys, and bladder every minute up to twelve minutes; then at fifteen, eighteen, twenty-one, twenty-five, twenty-six, twenty-seven and thirty minutes.

The cases were divided into age groups, "under fifty," and "over fifty." Each group was subdivided into those who had drunk a glass of water fifteen to thirty minutes before injection, and those who were strictly dehydrated. Graphs of average counter readings from each group and subgroup were drawn. Comparison of the kidney graphs is instructive. In the "under fifty" group after an initial steep rise to six or eight minutes, there is a steady gradual rise to twenty-one minutes, followed by a gradual fall to thirty minutes. In the "over fifty" group the maximum counter readings are obtained at four minutes, followed by a fairly steep drop to nine or ten minutes, where the graph remains about level to twenty-five. This agrees with the frequent observation of obtaining the best pyelograms in the five or ten minute films.

Counter readings for the liver and spleen fluctuate considerably up to about ten minutes in both groups, and then settle down to a fairly even level.

In the "under fifty" group with water before the injection the general form of the kidney graph is similar to that of the dehydrated "under fifty" group, although the readings are at a much higher level. In the "over fifty" group with water, on the other hand, the level is not only higher but there is a sharp rise to seven or eight minutes, followed by a gradual rise to eighteen minutes. This would indicate that the giving of water to elderly patients fifteen to thirty minutes before the injection may be advantageous in that it converts a narrow peak period into a broad one, and we may thus succeed in combining an adequately high concentration of contrast medium with a relatively slow fall, and the later films of a series should show better filling than those made earlier.—*Samuel G. Henderson, M.D.*

McClure, Richard F. Hypaque, a safe medium for pediatric intravenous urography. *Radiology*, July, 1957, *69*, 101–102. (Address: 1921 S. Catalina Ave., Redondo Beach, Calif.)

The author's report concerns the use of hypaque for intravenous urography in the pediatric age group. It summarizes his experiences with this drug in the study of 226 children, varying in age from two weeks to fifteen years. All were skin tested prior to the examination and 16 patients who showed positive skin reactions had their examinations cancelled. Of the 210 receiving the hypaque intravenously in doses ranging from 8 cc. to 20 cc. depending on age, only 8 experienced any reaction. This was limited to nausea and vomiting and no severe reactions were encountered. The opacification of the urinary tract was reported to be of uniformly good quality in all cases.—*John S. Alexander, M.D.*

Williams, John I., Carson, Russell B., and Wells, W. Dotson. (Fort Lauderdale, Fla.) Reflux ureteropyelograms in children. *South. M. J.*, July, 1957, *50*, 845–851.

The purpose of the paper is to stress cystography

as an indispensable diagnostic aid in the complete evaluation of a pediatric urologic problem. By this procedure, it is possible to demonstrate vesicoureteral reflux when other diagnostic procedures have offered little information.

The preferable method of performing the cystographic examination is without general anesthesia. The child is urged to void, if he is old enough to cooperate, and then the bladder is catheterized for residual urine. The authors use diodrast 35 per cent or skiodan 40 per cent as the contrast medium, diluted to about one-third strength with distilled water warmed to body temperature. A more dilute solution will not give adequate contrast to demonstrate the ureters. The bladder is filled under gravity flow to a point of discomfort or until a pressure of 18 cm. to 20 cm. of water is obtained. A delayed cystogram is obtained whenever the initial cystogram does not reveal reflux; films are exposed at ten and twenty minute intervals.

Three clinical cases are presented in which retrograde cystography demonstrated abnormalities which were not revealed by retrograde pyelography in 2 cases and not shown by excretory urography in 1 case.

The significance of vesicoureteral reflux is discussed as there is a divergence of opinion among urologists regarding the statement that such reflux does not occur in normal patients. The authors feel that if reflux is seen in a dilated ureter and renal pelvis, it can be considered to be pathologic.—*J. F. Weigen, M.D.*

SKELETAL SYSTEM

CHIAPPA, S. Sul significato di alcune formazioni ossee paravertebrali. (The significance of certain paravertebral bone formations.) *Ann. radiol. diag.*, 1956, *29*, No. 5, 379–406. (From: Istituto di Radiologia e Terapia Fisica dell'-Università, Pavia, Italy.)

The purpose of this paper is to discuss the subject of bone formations along the anterior surfaces of the lower dorsal and lumbar vertebrae.

In 1931 Janker described the "persistent epiphyses" in these vertebrae. They are considered secondary centers of ossification of the marginal rings which undergo ossification between the tenth and fifteenth year of life. Since such epiphyses of the marginal rings of the vertebrae are much more common in certain lower forms of life—gorilla and orang-outang, they may be referred to in humans as rudimentary epiphyses of the vertebrae. They are characterized by: (1) Location in the region of the marginal ring—have a smooth contour and the structure of spongy bone; (2) the edge of the vertebra shows a smooth defect at the site of the bone formation; (3) normal appearance of the intervertebral disk; (4) although only a single vertebra may be involved, multiple involvement is also possible; and (5) long term follow-up studies show no changes in roentgenographic appearance over the years.

A plausible explanation as regards pathogenesis is that the bone formation may be due to herniation of the intervertebral disk. The bone substance reacts to maintain the herniated disk by forming a barrier. This theory of herniation of the intervertebral disk was well substantiated by the studies conducted by Schmorl.

Niedner, who continued the work started by Schmorl, found that this herniation of the disk involves usually the lumbar and sacral vertebrae; the bone formation is usually much larger and affects the superior anterior surface of the vertebral body.

Lindblom has been able to demonstrate the herniated disk in these cases by means of diskography. The characteristic findings are: (1) The bone formation is always located on the anterior superior aspect of the vertebra, usually lumbar or sacral segments of the spine; (2) the separation between the bone formation and vertebral body is wide and the contours are somewhat irregular; (3) the adjoining surfaces of the bone formation and the vertebral body are somewhat sclerotic; and (4) the intervertebral disk is altered either in height or contour, there being calcification of the intervertebral disk or of the fibrous ligament.

Trauma, inflammation or degenerative changes are possible causative factors. The alterations are more often found in older patients. The differential diagnosis must include chronic infectious processes such as tuberculous caries of the vertebral bodies and aseptic necrosis. In cases of aseptic necrosis, the bone undergoes decalcification in the early phase; later the bone recalcifies and after healing the annular ring appears irregular.

The author's considerations are based on examination of 3,000 lumbar spines. All patients were over twenty-five years of age. In this series 46 cases showed paravertebral bone formations. The fourth lumbar vertebra was most frequently involved. In the differential diagnosis, acute trauma, chronic infectious processes or aseptic necrosis were not a serious problem. Perhaps the follow-up roentgenographic examinations which in some cases were over long periods of time made this problem easier for the author. However, when we are confronted with roentgenograms of a single examination and asked to give an opinion—the problem is not so simple.—*Peter E. Russo, M.D.*

BLOOD AND LYMPH SYSTEM

SICHEL, D., WITZ, J. P., MEYER, A., and M^me^ VOEGTLIN. Intérêt des tomographies obliques et transverso-axiales dans le diagnostic de la coarctation de l'aorte chez l'adulte. (Importance of oblique and transverso-axial laminagraphy in the diagnosis of coarctation

of the aorta in the adult.) *J. de radiol., d'électrol. et de méd. nucléaire*, May–June, 1957, *38*, 398–404. (From: Service central de Radiologie and Clinque Chirurgicale B, Strasbourg, France.)

It is important to diagnose early a congenital stenosis of the aorta because the surgical risk seems to augment with age. The stenosis, which is more or less complete, starts distal to the origin of the left subclavian artery at the point of insertion of the arterial ligament. It begins to cause hypertension in early adulthood and if not treated surgically will cause death before forty.

Roentgenology plays an important role in the confirmation of the diagnosis of this congenital anomaly of the thoracic aorta. Thus it will reveal a funicular cardiovascular silhouette, a clearcut hypertrophy of the left ventricle and the almost pathognomonic rib erosions and notchings. In 25 per cent of cases, rib notchings are absent. Oblique views sometimes help demonstrate these erosions.

For exact localization and extent of stenosis, angiocardiography and retrograde aortography via radial or carotid arteries are of some value; but they also have some shortcomings and handicaps. Hence the authors resort to the relatively easier laminagraphy, using the left anterior oblique (parallel to the plane of the arch of the arota) and the transversoaxial (parallel to the horizontal plane) positions.

Fine laminagrams of 3 cases are presented and clinical, roentgen and angiocardiographic findings are discussed in detail.—*Jirair N. Sarian, M.D.*

Lodwick, Gwilym S., and Gladstone, William S. Correlation of anatomic and roentgen changes in arteriosclerosis and syphilis of the ascending aorta. *Radiology*, July, 1957, *69*, 70–78. (Address: G. S. Lodwick, School of Medicine, University of Missouri, Columbia, Mo.)

The authors present a comparative study of calcification of the ascending aorta in arteriosclerosis and syphilis, based on: (1) roentgenograms of 72 autopsy specimens of aortas; and (2) on 62 posteroanterior chest roentgenograms which demonstrated calcification of the ascending aorta.

Although calcification frequently occurs in the ascending aorta in atherosclerosis, such is rarely seen in the chest roentgenogram due to its medial location. Typically, atherosclerotic calcification is greatest in the abdominal aorta where the roentgenogram demonstrates plaques which are large, dense, angular and isolated. In contrast, the calcification of the aorta in syphilis is greatest in the ascending aorta and aortic arch with the plaques being numerous, angular, flaky and smaller then atherosclerotic calcific plaques.

A method of determining aortic width and length is presented, whereby the values are summated as an aortic index for comparative purposes. A unique transparent plastic scale is described and illustrated.

Of the 62 chest roentgenograms showing calcification of the ascending aorta, data from serologic tests for syphilis were available in 61 cases, from which the authors concluded that such clacification was due to syphilis in at least 80 per cent of cases. The correlation with proved syphilis approaches 90 per cent or better if the elongation and tortuosity of the aorta, as measured by the aortic index, is additionally considered.—*E. B. Best, M.D.*

Figley, Melvin M., and Bagshaw, Malcolm A. Angiocardiographic aspects of constrictive pericarditis. *Radiology*, July, 1957, *69*, 46–53. (Address: Department of Radiology, University Hospital, Ann Arbor, Mich.)

Constrictive pericarditis can ordinarily be recognized on the basis of history, physical findings, and simple laboratory observations. Supporting evidence is generally provided by simple roentgen examination. Direct demonstration of pericardial abnormality by venous angiocardiography provides another approach.

The angiocardiograms of 8 patients with surgically verified constrictive pericarditis, 30 individuals with no clinical evidence of pericardial disease, and 6 with pericardial effusion (3 verified by pericardial tap) were studied. Manual injection of the contrast medium (urokon 70 per cent), serial filming at the rate of 1.3 or 2 roentgenograms per second, and registration of exposure on simultaneous electrocardiograms were used. The thickness of the right heart wall was observed in each patient. Measurements were made on at least three roentgenograms of each patient. For estimation of the speed of the intrathoracic circulation, the time in seconds between the appearance of the contrast medium in the superior vena cava and the ascending aorta was noted.

Normally the right heart border rarely exceeds 4 mm. in width. It varied from 4.5 to 8.5 mm. in constrictive pericarditis and 10 to 15 mm. in pericardial effusion. Accessory angiocardiographic signs of constrictive pericarditis are straightening and rigidity of the right atrial border, superior and inferior vena caval dilatation, slowing of the intrathoracic circulation, a right ventricle of normal or small size, and slight left atrial dilatation.—*Arno W. Sommer, M.D.*

Heinz, Randall, and Abrams, Herbert L. Radiologic aspects of operable heart disease. IV. The variable appearance of constrictive pericarditis. *Radiology*, July, 1957, *69*, 54–62. (Address: H. L. Abrams, Stanford University Hospitals, San Francisco 15, Calif.)

Twenty-one cases of surgically proved constric-

tive pericarditis which had been intensively studied both clinically and roentgenologically were analyzed. Signs and symptoms are discussed as are preoperative electrocardiograms and cardiac catheterization studies.

Analysis of the roentgenologic findings showed that there is no "characteristic" roentgen picture. A "small heart" as frequently described is not always present and in many cases the cardiac silhouette is enlarged. Normal pulsation may be present fluoroscopically and kymographically. Pericardial calcification was demonstrated in only about half of the cases studied and was located, in descending order of frequency, in the right ventricular surface, the diaphragmatic surface, the left ventricular surface, the right atrial surface, and the left atrial surface. Its presence is helpful when constrictive pericarditis is suspected but its absence does not rule it out. The right ventricle, pulmonary artery segment and the hilar pulmonary arteries are commonly enlarged, and pulmonary engorgement is apparent.

The authors conclude that if constrictive pericarditis is suspected clinically, such observations as cardiac enlargement, cardiac pulsations within the normal range, and roentgenologic evidence of pulmonary artery and right ventricular enlargement should not be considered incompatible with that diagnosis.—*Donald N. Dysart, M.D.*

HARE, W. S. C. Damage to the spinal cord during translumbar aortography. *J. Fac. Radiologists*, April, 1957, *8*, 258–266. (From: The Department of Radiology, Royal Melbourne Hospital, Melbourne, Australia.)

Several causes of spinal cord damage during aortography have been suggested by various authors. Probably the most commonly considered possibility is that of cord damage by the needle point during aortic puncture. The author believes that such damage may occur from either ischemia or chemotoxic injury. The blood supply of the spinal cord comes from the anterior and posterior spinal arteries. The anterior spinal artery supplies the anterior two-thirds of the cord. It arises from the vertebral artery and is augmented by segmentally placed anterior radicular arteries arising from the lateral spinal (intervertebral) arteries. In the region of the conus medullaris the anterior spinal artery bifurcates, each branch passing posteriorly to anastomose with a posterior spinal artery. The largest anterior radicular artery, arteria radicularis magna anterior, is in the lower thoracic or lumbar region, arising any place between T-8 and L-4. It is unpaired and usually arises from the left side, and it is concerned with vascular supply to the cord substance. Occlusion of a segmental artery giving rise to this artery might produce ischemia and infarction of the lower portion of the spinal cord.

The vessels of the spinal cord are quite sensitive to the chemotoxic effects of contrast media. The arrangement of the blood supply to the cord is such that only a small amount of the medium injected reaches the cord during aortography. But chemotoxic injury is more likely to occur when one rapidly injects larger volumes of highly concentrated media into the aorta. Hence, the author thinks it is unwise to inject more than 20 cc. of urokon sodium (70 per cent) rapidly into the aorta, and such injection should not be repeated at any one examination since the chemotoxic effect is cumulative.

The case report of a 59-year old woman is given in whom 45 cc. of 70 per cent urokon sodium was injected within four seconds. Later at the same examination an additional amount of 32 cc. of 70 per cent urokon sodium was injected. This was followed by a flaccid paraplegia of the lower extremities. The patient died with recurrent urinary tract infections about four months later. Autopsy revealed a huge retroperitoneal cyst with fibrosarcomatous nodules. In addition, there was gross demyelinization in the mid-thoracic region of the cord, and secondary demyelinization had extended upward and downward from this level. It was thought that the most likely cause of the demyelinization was a chemotoxic effect of the contrast material used.—*Samuel G. Henderson, M.D.*

RABAIOTTI, A. and MALCHIODI, C. L'Angiografia come mezzo di diagnosi dei tumori dell'osso e delle parti molli. (Use of angiography in the diagnosis of tumors of bone and soft tissues.) *Ann. radiol. diag.*, 1956, *29*, No. 5, 352–369. (From: Istituto di Radiologia e del Radium dell'Università e Degli Ospedali Riuniti di Parma and Istituto di Clinica Chirurgica Generale dell'Università di Parma, Parma, Italy.)

The authors bring to our attention how useful angiography has been in the detection of intracranial, renal and tumors in other parts of the body. They further contend that this form of investigation aids in bone and soft tissue tumors, in determining the nature of the disease, whether benign or malignant, and in ascertaining the extent of the tumor. In many cases it may replace the biopsy prior to definitive therapy.

The authors follow the criteria of previous workers such as Dos Santos, Fariñas, Inckan, Columella and Mucchi, Fontaine *et al.* to determine if a tumor of bone or soft parts is benign or malignant. The signs of malignancy are: (1) Increased vascularity with vessels penetrating the tumor mass; (2) uniform vascularity throughout the tumor mass; (3) pooling of the contrast medium within the tumor; (4) direct venous channels draining the tumor without interposing arterioles or capillaries; (5) a vascular pattern which follows the direction of growth of the tumor by new blood vessels; (6) displacement of the normal

arterial tree caused by the expanding neoplasm; (7) newly formed arteries supplying the tumor with a triangular appearance in entering the neoplasm; and (8) an abrupt termination of the normal blood supply at the site of the tumor formation. This last category was observed in many cases by the authors.

This article contains many fine illustrations. It states that many malignant neoplasms of bone and soft tissues can be diagnosed in this manner. It seems to the reviewer that its greatest advantage lies in the fact that the extent of the tumor can be studied, thus being most helpful in planning the treatment. Biopsy, however, still remains the only method by which the true nature of the tumor can be identified. —*Peter E. Russo, M.D.*

Morton, S. A., and Bryne, R. W. Scanographic methods in visualization of the blood vessels and skeleton. *Radiology*, July, 1957, *69*, 63–69. (Address: S. A. Morton, 3321 North Maryland Avenue, Milwaukee 11, Wis.)

The authors describe a scanographic procedure for the demonstration of the arterial system of the entire lower extremity with one injection and a single roentgen ray exposure. Their technique is based on a method described by Astle and Wallace-Jones.

Several parts of equipment were devised. These include a 10-inch cone, to the end of which is fastened a piece of lead $\frac{1}{8}$ inch thick, with a narrow slit in it, 3 inches long and $\frac{1}{8}$ inch wide, and a small hand-operated winch having a metal crank with a shaft $\frac{1}{2}$ inch in diameter. A 14×36 inch cassette is used, loaded with two 14×17 inch films carefully butted end to end.

For femoral arteriography the patient is placed on his back on the roentgenographic table, with the 14×36 inch cassette positioned under the leg. The cone is attached to the tube so that the slit is at right angles to the long axis of the leg. The cord from the winch is fastened to the tube stand. The timer is set for twelve to fifteen seconds. For the average leg an eight second exposure, five seconds above the knee and three seconds below, is used. The tube progresses down the leg so that the band of radiation virtually follows the opaque medium as it progresses. It is thus possible to visualize the femoral artery and all its branches with a single injection. Some variation of speed is necessary if an arterial block is present.—*Arno W. Sommer, M.D.*

General

Stieve, F. E. Über die Dominante im Röntgenbild; Ein Beitrag zur generellen Anwendung der Belichtungsautomatik im Aufnahmebetrieb. (The dominant in the roentgen image; a contribution to the general use of automatic exposures in film taking.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, July, 1957, *87*, 80–100. (Address: Ziemssenstr. 1, München 15, Germany.)

According to Franke, every roentgen image has a zone (dominant), the optimal reproduction of which determines the value of the film. When automatic exposures are made, it is important only to establish the average blackening of this dominant. Accordingly, it is necessary that the dominant of the image be known, and that the measuring instrument registers, during the exposure, the rays which are effective on that spot under the object examined.

The author attempts to determine how wide the dominant is in the various roentgen examinations and how large the measuring chamber must be to achieve the proper gradations of blackening. The dominant is the diagnostically most important zone of a film and the average blackening should encompass the average value of the smallest and greatest blackening of the incidental recognizable details on the film. Most dominants lie in the region of the central ray (vertebral column, skull) and thus also in the middle of the cassette, even when the organs themseves do not lie in the mid-axis of the body (gallbladder, knee, etc.). These may be called central dominants. In those instances where the most important parts of the film are paired or symmetric (lungs, kidneys, hip joints), and where the dominant lies outside the horizontal mid-line, the dominants may be termed excentric.

The automatic exposure instrument should represent as much as possible an invisible aid and not lead to further complicate the technique of the taking of the roentgenogram. When there are large, relative homogeneous dominants with little contrast in their periphery, the measuring field may be smaller than the dominant. In dominants with marked contrast in their periphery, the measuring field must never be larger than the dominant itself, if the dominant should demonstrate the desired average blackening. In roentgenographing the abdomen and pelvis, it is immaterial whether the measuring field lies in the region of the vertebral column or in the adjacent soft tissues. In case of the lungs under pathologic conditions, the situation is completely different and the measuring chambers are of no avail here.

The above statements relative to the size of the measuring fields in automatic filming devices apply only under the following conditions: (1) The measuring instrument should be able to adjust automatically, with one single sensitivity setting, to similar blackening on a film, regardless of the voltage employed, size of the field, even size of the measuring field and thickness of the patient; and (2) the same dose, independent of the voltage used, should produce the same amount of blackening on the film.

On the basis of theoretic considerations and statistical measurements three different arrangements of

field size and position (either in the central ray or outside the axis of symmetry) are given, which guarantee a correct exposure for all main types of views.

Under certain conditions, mentioned in detail, it is possible to obtain a constant blackening of the film almost independently from the quality of the rays used in the diagnostic field. With the automatic timer the current factor of 1.25 for every centimeter increase in thickness, as known from exposure tables, is preserved. Therefore, the arrangement can be recommended for routine use in diagnostic roentgenology.—*Samuel Richman, M.D.*

HECKMANN, K. Die bivisuelle Röntgenaufnahme. (Bivisual roentgen filming.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, July 1957, *87*, 64–75. (Address: Habsburgerplatz 1, München 13, Germany.)

The principle of bivisual roentgen examination rests on the technique of exposure of different parts of the object on the same film at various optimal angles of inclination of the ray. Each one-half of the film is exposed separately and the cassette is moved after the first exposure so that the other one-half is similarly exposed. For the technique to be successful, the border between the parts of the film must not be visible and there must be no gap or overlapping of the exposed part. These aims may be accomplished by the insertion of a metal filter close to the tube target so that exactly one-half of the film is blocked off on each exposure and by using a laminagraphic apparatus, the central ray may be so directed as to enter precisely at the same point on each exposure. It is extremely important to have the central ray exactly in the middle of the tube opening so that the inserted metal filter extends just to the central ray. Otherwise, asymmetric films will be obtained. The radiation dosage to the patient is not any larger by this technique as compared to the usual procedures.

The author has found his technique very valuable in the examination of the cervical spine by eliminating the projection of the mandible over the vertebrae. He has been able to demonstrate the cervical intervertebral foramina very well by altering the angle of the central ray. Also, the apophyseal joints of the entire vertebral spine may be similarly brought out. This technique has been especially useful in the examination of the thoracic spine, the upper one-half being given less exposure than the lower one-half of the spine. Equally well has the author been successful in filming the lumbosacral and sacroiliac areas, merely by angulating the tube appropriately during each of the two exposures.—*Samuel Richman, M.D.*

TUDDENHAM, WILLIAM J. Half-value depth and fall-off ratio as functions of portal area, target-skin distance, and half-value layer. *Radiology*, July, 1957, *69*, 79–87. (Address: 3400 Spruce St., Philadelphia 4, Pa.)

The half-value depth, or $D\frac{1}{2}$, is the depth in tissue at which the radiation dose equals 50 per cent of the surface dose and is a clinical expression of the penetrating power of a specified radiation beam. Since D 9/10 is the depth in tissue at which the radiation dose equals 10 per cent of the surface dose, the fall-off ratio is D 9/10 of a specified beam divided by its $D\frac{1}{2}$ and this represents a clinical expression of the absorption rate of the specified radiation in tissue.

These determinations are thought to be of value for several reasons. First, they are of use in specifying superficial radiation beams and they will facilitate treatment planning for superficial lesions. Second, they will provide an index of the distribution of radiation of higher energy in tissue as influenced by the effect of changing kilovoltage, external filter, portal size, and target-skin distance. Third, determination of the half-value depth of the incident radiation is necessary for the calculation of the integral dose.

The author presents the values of half-value depths and fall-off ratios for wide range of half-value layers, portal areas, and target-skin distances. It is thought that these data will be of use in teaching, and in treatment planning in clinical radiation therapy.—*Donald N. Dysart, M.D.*

BOHATIRCHUK, F. P. Erfahrungen der letzten zwanzig Jahre in der Anwendung der Mikroröntgenographie (Historöntgeno- oder Historadiographie) in der medizinischen Forschung. (Experiences in the last twenty years with the use of microroentgenography [historoentgenography or historadiography] in medical research.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, July, 1957, *87*, 44–56. (Address: Department of Anatomy, University of Ottawa, Ottawa, Canada.)

Since roentgen rays are not reflected, it is not possible to use the light microscope in direct roentgen microscopy. There exist two possibilities to overcome this difficulty; namely, through the direct method and the indirect method.

By the direct method, in which the shadow produced by roentgen rays as near as possible from a point focus, is projected upon an emulsion sheet placed at a known distance, one gets roentgen enlargements in relation to the distance of the roentgen rays. Several technical difficulties must be overcome before this form of roentgen microscopy can be used in medical research.

The indirect method of microroentgenography, frequently called "contact-roentgenography," depends on the roentgenography of a very thin object with very soft roentgen rays on a film or plate having

a fine grain emulsion. The roentgenogram thus obtained is studied with the usual light microscope under various enlargements. The following factors must be considered: (a) The object in which the roentgen rays are absorbed; (b) roentgen rays of corresponding wave length; (c) low kilovoltage (8 to 12 kv.); (d) film or plate with fine grain emulsion; and (e) microscopic examination of the obtained roentgenogram. The smaller the difference of the linear absorption coefficient, the longer the roentgen wave length must be to show up the absorption difference. The histologic section myst be very thin, even, and smooth. There are methods of increasing the selective absorption difference of objects by the use of materials which absorb roentgen rays. The cells and connective tissue may become impregnated directly with the roentgen opaque material or this substance may be administered by the natural routes (microroentgen vasography).

By microroentgenography, new morphologic details may be demonstrated which cannot be shown with either the conventional methods of histology or photography. To obtain perfect microroentgenograms, the author recommends: (1) A roentgen tube with a focal point no larger than 1.5 mm.; (2) a fine grain emulsion; (3) a histologic section which when dry, is no thicker than 5–10 microns; (4) the best possible contact between the emulsion and the object; and (5) monochromatic rays, between 8 to 12 kv., irrespective of the nature and art of the object. By adhering to the above factors, the author has been able to obtain a magnification up to a maximum of 300 times. Larger magnifications have resulted in loss of contrast and sharpness.

Microroentgenography of tissues unaltered by the addition of other substances, has been done primarily on bones and other calcium containing tissues. Thus the distribution of the mineral salts in the ossicles of the inner ear, the presence of a temporary periosteal new bone formation in certain bone diseases, etc. have been demonstrated. By microroentgen vasography, the nature of the formation of bacterial emboli in the epiphyses of the bones in osteomyelitis, has been clarified. Barclay demonstrated the presence of a collateral circulation in his study of stomach injuries. Doran showed that the lesser curvature of the stomach contains an insufficient circulation of blood, thereby suggesting the presence of a higher incidence of ulcers in that region. Other valuable studies by Trueta on renal circulation, Saunders on heart muscle blood supply, etc. have been accomplished. After impregnation of the tissues with roentgen-opaque substances, such as thorotrast, studies have been made on cancer cells, nerve tissue, etc.—*Samuel Richman, M.D*

Miscellaneous

Lacassagne, A. (Paris, France.) Sur les mécanismes de la mort par irradiation corporelle totale. (On the mechanisms of death by whole body irradiation.) *J. de radiol., d'électrol. et de méd. nucléaire*, March–April, 1957, *38*, 183–186.

Whole body irradiation may result in rapid or even sudden death, or there may be delayed death depending on the deficiency of certain organs or systems. The survival curve in mice can be plotted as a function of the dose. With increasing dose, the curve presents three characteristic segments. Between 100 and 1,000 r, the curve descends progressively; the animals succumb between three and twenty days; at 400 r, the average is eleven days. Between 1,000 r and 10,000 r, the curve is a plateau; the radiation effects between these limits are independent of dose and the average survival time is about three and a half days. Above 10,000–15,000 r and up to 30,000 r the curve again descends rapidly; the animals die in less than three days, and even in an hour when the dose approaches 30,000 r. It is also remarkable that in order to produce death in less than three and a half days, it is necessary only to irradiate the head of the animal. Doses of 2,000 r or more to the intestinal region will produce death in three and a half days. Crossfire of the body with doses of 25,000–50,000 r produces death in three to ten hours. Microscopic examination shows complete devastation even of tissues thought to be little radiosensitive.

The independence of dose and survival time in the plateau segment of the curve seems to be related to the adrenal function when the trunk is irradiated and to the pituitary function when the head is exposed. Between these dose levels, these glands can compensate as the dose increases, but around 15,000 r this compensation breaks down. It is thought that irradiation produces a typical alarm reaction and perhaps in the plateau segment, the second phase of the reaction, resistance is manifest. Doses over 15,000 r rapidly result in the third or exhaustion phase. It is known that even very small doses of irradiation produce a certain amount of cellular death, also that toxemia and nonspecific shock may appear without causing death. The latter can be considered as a sort of extension of the process of morphologic and functional cellular destruction.

The immediate consequences of whole body irradiation are: (1) hematologic, with leukopenia, thrombocytopenia, increased coagulation time and anemia, and with purpura appearing in six to seven days, followed by hemorrhagic effusions and death in seven to ten days after irradiation; (2) bacteremic, apparently due to a breakdown in the intestinal barrier; (3) polyvisceral, particularly involving the liver, spleen, kidneys and intestines, when doses are around 1,000 r; (4) glandular, especially of those controlling the regulatory mechanisms, when the dose exceeds 15,000 r, the adrenal and pituitary surviving longest; and (5) instantaneous, death being due to molecular disintegrations.

The secondary consequences of whole body irradiation may appear even if the animal survives for more than a month after a sublethal dose. The damage is never completely repaired. Certain organs are impoverished and transmittable anomalies appear. Some think that life is shortened. There is diminished resistance to infection and trauma, chronic anemia becoming aplastic and malnutrition following atrophy of intestinal glands; liver cirrhosis, nephritis, leukemia and various cancers may develop.—*Marcy L. Sussman, M.D.*

KROKOWSKI, E., and EHLING, U. Wachstumshemmung der Linse am röntgenbestrahlten Kaninchenauge. (Growth inhibition of the lens of the irradiated rabbit's eye.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, August, 1957, *87*, 222–225. (Address: E. Krokowski, Strahleninstitut der Freien Universität, Spandauer Damm 130, Berlin-Charlottenburg, Germany.)

In a preceding article (April 1957, *86*, 469–477, abstracted in this JOURNAL Oct. 1957, *78*, 749–750) experiments were reported on the quality and dose of roentgen rays necessary to produce a cataract.

In the present article the authors deal with growth inhibition of the lens due to irradiation. When the damaged eyes of the rabbits were removed, a definite retardation of growth could be observed each time regardless of the applied dose.

It was found that already minimal quantities of roentgen rays could cause a growth arrest, as, for example, doses which were too small to produce even clouding of the lens. Histologic studies revealed that the germinative zone of the growing lens proved very radiosensitive. When mitosis in the epithelial layer was inhibited or eliminated by the roentgen rays, full development of the lens was no longer possible.

Although a tolerance dose of 200 r does not cause any clouding of the lens, it must be remembered that even the smallest dose of roentgen rays may inhibit the growth of the lens. Therefore, it is concluded that roentgenographic examination of the head and face in infants may not be entirely without harm to the growth of the lens.—*Ernest Kraft, M.D.*

DUPLAN, J. F., BENEX, J., and DESCHIENS, R. Les hyperéosinophilies expérimentales par irradiation x totale chez le cobaye. (Experimental hypereosinophilia by total body x-irradiation of guinea pigs.) *J. de radiol., d'électrol. et de méd. nucléaire*, May–June, 1957, *38*, 416–417. (From: Institut Pasteur, Service de Radiobiologie et Service de Parasitologie, Paris, France.)

The authors report that under certain appropriate conditions such as total body irradiation, nonhomogeneous distribution of radiation (100 kv.) and fractionated mean doses, it is possible to promote regularly hypereosinophilia in guinea pigs. This increase in eosinophils, however, does not appear to be in relation to a regenerative medulla, nor is it accompanied by hyperleukocytosis of polynucleosis, but on the contrary, it is coincident with a neutropenia as we can observe regularly in man.

In conclusion, the authors feel that experimental eosinophilia in guinea pigs is somewhat similar to professional eosinophilia. An increase in eosinophils in a man regularly exposed to radioactivity should be considered as a sign of alarm.—*Maurice Dufresne, M.D.*